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HIS MOST GRACIOUS MAJESTY

KING EDWARD VII

PASSED AWAY MAY 6, 1910,

BELOVED AND MOURNED BY ALL HIS PEOPLE, AFTER A SHORT BUT STRENUOUS REIGN OF NINE YEARS, DEVOTED TO ALL GOOD WORKS IN THE BRITISH DOMINIONS AND TO THE WELL-BEING AND PEACE OF THE NATIONS.

ORIGINAL ARTICLES.

I.—Notes on a Collection of Fossil Plants from the Newent Coal-field (Gloucestershire).

By E. A. Newell Arber, M.A., F.L.S., F.G.S.

IT has been known for more than a hundred years past that a small tract of Upper Carboniferous rocks occurs in North-West Gloucestershire, between May Hill and the Malverns. The beds crop out in the neighbourhood of Newent, a village lying some ten miles to the north-west of Gloucester. The field, however, is almost entirely concealed beneath Triassic rocks. The measures are productive, and have been worked at various periods on a small scale, though the greater portion of the basin remains to this day unexplored.

The geology of the district was first studied by the celebrated William Smith, in 1803 and 1805. In his manuscript notes,[1] published in 1844, there is a section of the sinking at Boulsden, or, as it was then apparently called, 'Bowsden,' one mile south-west of Newent, where a coal-seam crops out. In the past the coal has been more extensively worked at this spot than at any other in the district.

It is not proposed to enter here into the geology of this tract of Carboniferous rocks. What is known on the subject will be found in the papers by Weaver,[2] Maclauchlan,[3] Murchison,[4] and especially in the excellent Survey memoir dealing with the district of the Malvern

[1] J. Phillips, *Memoirs of William Smith*, 1844, pp. 54, 58.
[2] T. Weaver, Trans. Geol. Soc., 1824, ser. II, vol. i, pt. ii, p. 317.
[3] H. Maclauchlan, Trans. Geol. Soc., 1837, ser. II, vol. v, pt. i, p. 203.
[4] R. I. Murchison, Proc. Geol. Soc., 1835, vol. ii, No. 38, p. 121; see also *The Silurian System*, etc., London, 1839, p. 153.

Hills by John Phillips.[1] So far as I am aware no additions have been made to our knowledge on this subject since 1848.

I have for some years past been occupied with a study of the distribution of fossil plants in the Forest of Dean, which lies roughly between the Newent and Bristol Coal-fields. The flora of the Bristol Coal-field has recently been extended and revised by my friend and former pupil Mr. Lillie.[2] My attention was thus naturally turned to the Newent tract, and after some correspondence with Dr. Theodore Groom, who, I understand, will shortly publish a paper including a geological study of this part of Gloucestershire, I visited the district last October with a view to collecting such plant remains as could be obtained. I found, as I had anticipated, that there are practically no exposures of the Coal-measures at the present time which offer any opportunity for collecting fossil plants. I had, however, the good fortune to secure the co-operation of Mr. I. Rogers, of Bideford, who very kindly spent some days with me at Newent, and, to his exceptional skill as a collector, such specimens as we were able to obtain are largely due. To him I owe many thanks. I have also to express my indebtedness to a grant from the Government Grant Committee of the Royal Society for defraying the expenses of the field-work.

It fortunately happened that, shortly before my visit, a well had been sunk at Great Boulsden, about 90 feet deep, on the exact site of the old abandoned workings for coal in this locality. The upper 6 feet, I was told, consisted of red rocks, no doubt Trias, and the rest of the section appeared to be Coal-measures. I was also informed that no seam of coal had been passed through, but that it was expected that the coal would be reached at a depth of about 120 feet. At the time when I discovered this sinking, the heap of debris thrown out of the well had unfortunately become badly weathered, partly owing no doubt to the wet nature of last summer. The shales were thus extremely soft and very fragmentary. Collecting was performed by means of the blade of a penknife. However, after several days work, Mr. Rogers and I managed to obtain a few specimens which could be determined specifically, and which will be discussed here.

I may perhaps mention that, through the kindness of Mr. O. T. Price of Boulsden Croft, Newent, I obtained some interesting information as to the year in which the coal was first worked at Boulsden, which does not appear to have been known to those who have written on the geology of this district. Mr. Price showed me a copy of the *Gloucester Journal* for April 26, 1890, in which there was an article recalling the excitement due to the discovery of coal at Boulsden one hundred years previously. Quotations from the *Hereford Journal* of July 7 and 14, 1790, were cited in which it was stated that coal had been raised and burnt in Hereford and Gloucester during the summer of that year. The cost then was 16*s.* a load. Apparently the enterprise did not prove profitable, for the shafts appear to have been abandoned a few years later.

[1] J. Phillips, "The Malvern Hills": Mem. Geol. Surv., 1848, vol. ii, pt. i.
[2] D. G. Lillie, Geol. Mag., 1910, Dec. V, Vol. VII, p. 78.

Some thirty years ago, the Newent Colliery Company sank two shafts on the site of former workings below White House, about three-quarters of a mile due west of Oxenhall Church, to the north-west of Newent. These pits have also been long since abandoned. By digging, however, in the old waste-heaps of this colliery, Mr. Rogers was able to unearth a few fragments of fronds. These were the only other specimens which we could obtain, even after a careful examination of all the outcrops of the Coal-measures in the district.

So far as I am aware no plant remains have ever been previously collected from this coal-field, nor do I know of any reference to such specimens in any book or paper. The fossils discussed here are thus unique as regards locality.

A few fragmentary pith-casts of Calamites occur, one of which is possibly *Calamites Suckowi*, Brongn., but the specimens are too fragmentary to permit of specific determination. Two types of Calamite foliage were found, a single specimen of *Annularia radiata*, Brongn., and several examples of *Calamocladus equisetiformis* (Schloth.), which appears to be common.

Among the Fern-like fronds, those of *Pecopteris* are particularly abundant, and probably more so than any other plant. There appear to be at least three species. Unfortunately, not only does the fragmentary nature of the specimens render them unfavourable for specific determination, but the nervation is as a rule very indistinct. *Pecopteris oreopteridia* (Schloth.), the characteristic nervation of which is seen in several examples, almost certainly occurs and is particularly abundant. *Pecopteris Miltoni* (Artis) appears to be also common. Other fronds apparently belong to *Pecopteris arborescens* (Schloth.), but their attribution is more doubtful, for the nervation cannot be clearly seen in any example, though specimens do occur in which the veins are apparently simple.

Two small specimens, each showing a few pinnules of *Neuropteris rarinervis*, Bunb., were collected, in which the nerves are very clear and characteristic. Fragments of Sphenopterid fronds, recalling *Sphenopteris obtusiloba*, Brongn., were found, but are too small to be determined with certainty.

Small leafy branches of a *Lepidodendron* are frequent, and the characteristic striated bark[1] of an unknown genus, which has been found in several other coal-fields, is also represented. A single, poorly preserved leaf of *Cordaites* completes the list.

The above specimens were all collected from the well-sinking at Great Boulsden. From the disused Newent Colliery heaps, one or two specimens of *Neuropteris Scheuchzeri*, Hoffm., and a fragment of a pinnule with a net nervation, belonging either to *Linchopteris* or *Dictyopteris*, perhaps the former rather than the latter, were the only plants obtained, with the exception of some Lycopod macrospores.

The collection from the Newent Coal-field is too small to determine the horizon of the beds with certainty. So far as it goes it indicates that the zone is higher than the Middle Coal-measures, but whether Upper Transition Series or Upper Coal-measures cannot be definitely

[1] See Arber, Phil. Trans. Roy. Soc., ser. B, vol. cxcvii, p. 310, pl. xx, fig. 12.

decided at present. The presence of *Annularia radiata*, Brongn., and to a less extent that of *Neuropteris rarinervis*, Bunb., would seem to turn the balance in favour of the Upper Transition Series were it not for the abundance of Pecopterids and the possible occurrence of *Pecopteris arborescens* (Schloth.). Perhaps we may provisionally conclude that these beds belong, either to the highest portion of the Upper Transition Series, or the lower portion of the Upper Coal-measures.

II.—On the Glaciation of the Navis Valley in North Tirol.

By Alfred P. Young, Ph.D., F.G.S., F.L.S., etc.

(PLATES XIX AND XX.)

In a previous paper[1] it was shown that one prominent topographical feature of the Tarntal district, the great cirque called the 'Grübl', could be explained as the effect of erosion by a short ice-tongue which formed when the snow-line persisted for a time at about 2400 metres above sea-level. The basin-shaped hollow of the Upper Tarntal was held to be due to another stand of the snow-limit at 2650 metres. It remains to be seen whether these conclusions are supported by evidence of a similar nature collected over a wider area.

Evidence for Snow-lines in other parts.

The drainage basin of the Navis Valley is bounded on the south by a well-marked ridge in no part lower than 2250 metres, with several summits over 2400 metres; the highest, the Schafseiten Spitze, reaches 2604 metres. On the north slope of this ridge is a row of corries sufficiently conspicuous to be visible from the north slopes of the valley as shown in the photograph, Fig. 1, Pl. XIX. Two of these corries under the ridge between Bendelstein and Schafseiten Spitze certainly held at one time small lakes; the moraine dams at the outer lips are still well preserved at a level of about 2150 metres. The corries are evidently the beds of short ice-tongues which formed when the snow-line stood for a time at about 2250 or 2300 metres.

On the northern slopes of the Navis Valley the corries are not so well developed. On the east slope of the Mieselkopf[2] is a well-marked amphitheatre, the floor of which is somewhat ill-defined. Important accumulations of moraine material are found on these slopes mostly at levels below 2300 and above 2150 metres; these evidently belong to a high snow-line, the level of which was between 2350 and 2400 metres.

Under the ridge which bears the Schober Spitz, 2450 metres, is a small but pronounced lake-basin at a level of 2300 metres, indicating a snow-line at 2350 metres nearly.

Summing up the evidence from different parts of the drainage

[1] Geol. Mag., Dec. V, Vol. VI, No. VIII (August, 1909), p. 339.

[2] See accompanying map reproduced from the Geol. Mag., August, 1909, p. 341.

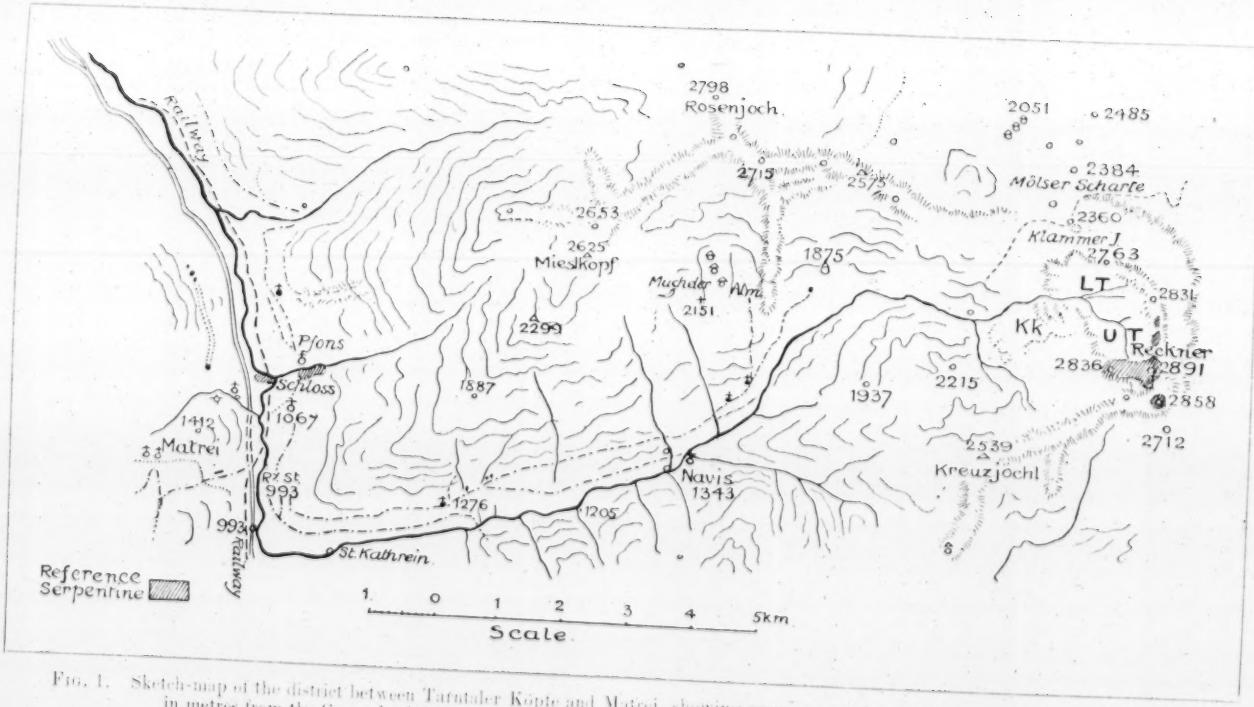


Fig. 1. Sketch-map of the district between Tarntaler Köpfe and Matrei, showing occurrences of serpentine. Height above sea-level in metres from the Generalstab-karte. U.T. Upper Tarntal; L.T. Lower Tarntal; Kk. Knappenkuchel.

area of the Navis Valley, we have for the probable height of the snow-line—

	Metres.
On slopes with north aspect under the Schafseiten ridge	2250 or 2300
At the Grübl with west aspect	2400
Slope with south aspect under Schober Spitz	2350
Slopes with east and south-east aspect under Mieselkopf	about 2350

Simple and Compound Corries.

The corries under the Schafseiten Spitze are so simple in form that they may have been excavated during a single stage of glaciation. The dams being still intact, it is clear that the stand in question was made in the course of the last retreat of the ice, marking a late phase in the Würm period of Penck. An earlier period is out of the question; the dams formed would have been swept away by the ice in the following advance.

At the Grübl, the great cirque under the Tarntal, the conditions are more complicated, and only to be explained on the assumption that the work of excavation commenced during one of the earlier glaciations. The rear wall of this cirque is over 300 metres in height. The whole of the water draining from the Upper and Lower Tarntal collects under the screes and reaches the Grübl in the form of big springs which come to the surface little above the floor of the cirque.

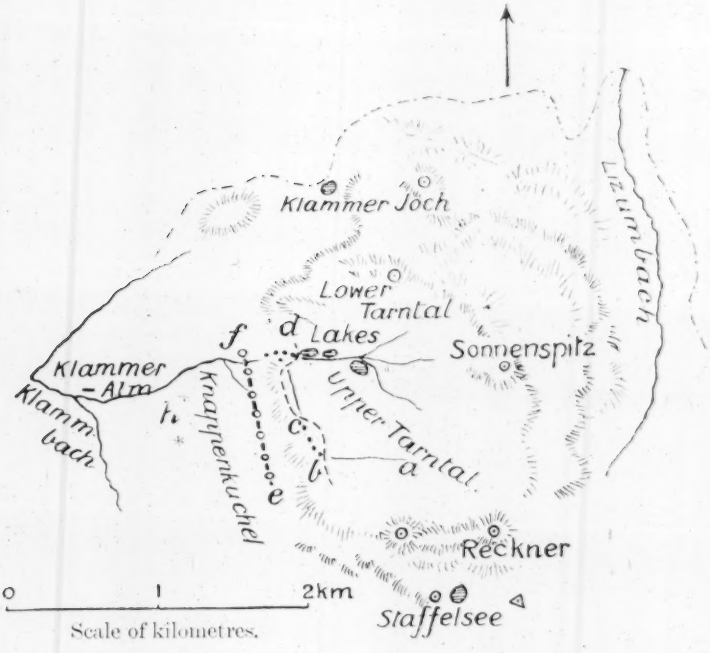
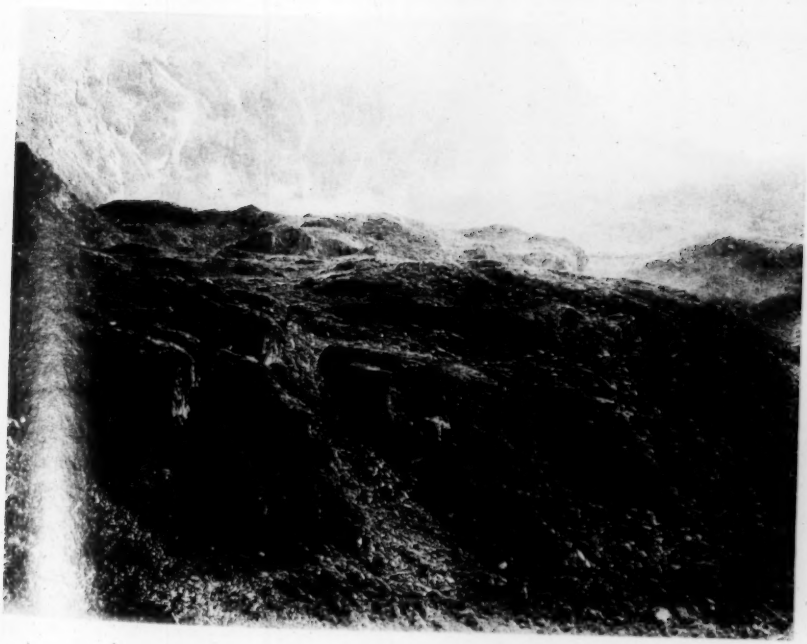


Fig. 2. Sketch-map of the Tarntal area.

b, *c*, *d*, brow of steep slope, forming the present rear wall of the Grübl; *e*, *f*, supposed position of the head of the rear wall of the older simple corrie; *h*, knolls of schist and 'Eisendolomit' at the lip of the Grübl.

FIG. 1.—Corries under Schafseiten ridge.



Beaucose, Calto.

FIG. 2.—Old Floor of the Grübl; the Cirque under the Tarntal.

The annexed diagram (Fig. 2) shows in plan the main hydrographical features. A pronounced north and south groove *c*, *d*, is seen to end at *d* at a level of about 2500 metres, just in front of the lower end of the Lower Tarntal. This groove was at one time the bed of the brook from Upper Tarntal, which was then tributary to the Lower Tarntal. By the retreat of the wall the connexion has been broken in two places, namely, along the dotted line *bc* and near the junction at *d*.

At this earlier stage the wall at the back of the Grübl stood further to the westward as shown by the broken line *e*, *f*. The Grübl was then a simple corrie and received the drainage of both the higher valleys below the junction at *d*. Two other important changes have since been brought about. The floor of the Upper Tarntal has been further excavated so that the level of the latest outlet is lower by some 20 metres than the old watercourse at *b*. The floor of the Grübl has also been further eroded. A former level of this floor is no doubt indicated by the small plain which now makes a conspicuous feature in the landscape as seen in Pl. XIX, Fig. 2. This plain is now some 20 or 30 metres above the corrie floor.

In the case of the Grübl the process of 'gnawing back' must have gone on at an unusually rapid pace, the vertical joints in the dolomitic rocks facilitating the work of demolition, most of which was effected when the snow-line stood at levels between 2200 and 2500.

As long as the floor of the corrie was above the snow-line the blocks may have been detached in great numbers, but being under firn could not have travelled very far. When the snow-line was above 2500 the ice-tongues were much reduced in mass and length and could contribute little to the transport of the boulders. We come back later to the detailed history of the erosion of the Grübl.

Block-wall and Block-waste.

The east and west ridge carrying the Reckner and Little Reckner summits is almost girdled by a great wall of serpentine blocks. The Staffelsee on the south side is somewhat below the foot of the wall. The ridge-line of the wall is at 2600 metres, in parts higher. Fig. 3 of Plate XX is a photograph taken from a knoll about 2600 metres high in the Upper Tarntal to the north-west of Reckner. The crest of the block-wall is seen projected against the snow-field in the middle of the picture and can be traced eastward as far as the contour can be followed to the left.

At first sight the wall might be taken for a moraine, from which, however, it differs in the absence of any binding material. Most probably it is the result of the demolition which went on when the snow-line stood for a time at 2650 metres; the building of the wall was thus contemporaneous with the work of the glacier-tongue which filled the Upper Tarntal during or since the last retreat. The blocks were loosened by alternate frost and thaw, and remained near their original site or rolled down the slope by their own weight till checked. The pile has no doubt received later accessions and is probably increasing still; but its growth was far more rapid when the snow-line was lower.

This form of disruption without transportation finds a striking illustration in the Gross Kaserer, 3270 metres, a subordinate summit of the Olperer group. This peak is now and probably has during Interglacial periods always been above the snow-line. The great crevasses which form between firn and glacier-ice are well developed some way below the summit. The appearance presented is that of a pile of big boulders; the standing rock is not seen. The massive rocks of the Olperer gneissic series break up into blocks too large to be disturbed by the movement of the firn. The mound, moreover, stands out above the firn and has no permanent covering of snow.

This mode of disintegration is not confined to glaciated tracts, and good examples of disruption with little movement are to be found on ancient land surfaces, such as the Indian Peninsula and parts of South Africa. In the Alps the 'Block-meere' or block-wastes are frequent in high ground; most of them were no doubt accumulated when the snow-line stood for a time at a corresponding level.

Erosion To-day in High Ground.

The effects of erosion hitherto treated belong as regards the Tarntal mass to past history, and are referred to conditions of climate other than those at present here prevailing. As already shown,[1] the climatic snow-line is still, in all probability, below the highest summits, and it is instructive to watch the forms of atmospheric activity of to-day.

The serpentine blocks above 2600 metres are covered with wart-like prominences a centimetre or so in diameter; these warts are found occasionally on standing rock nearly up to the summits. They are due to the rapid weathering of the serpentine round the more resistant bastites which form the projecting parts. The prominences are seen on blocks below 2600 metres; at the lower levels, however, they are much worn down and do not seem to be forming afresh. The chief agent in this form of weathering is the nearly pure water trickling from the melting snow which covers the ground for a considerable part of the year.

An instance of the same kind of work is furnished by the well-known 'Karren'. This form of sculpture is peculiar to calcareous rocks; straight grooves resembling the ruts of cart-wheels are crowded together in parallel series and often cover wide areas, the 'Karrenfelder'.[2] The ruts are determined by structures in the limestone, thin bands, bedding-planes, joints; they were no doubt formed under snow, when the snow-line stood at a corresponding level, and are due to the solvent action of nearly pure water. The 'Karren' are only found at high levels; they may be expected to furnish useful information concerning former stands of the snow-line.

A steep slope on the south side of the saddle between Reckner and Little Reckner is covered to a depth of several feet with an incoherent deposit of more or less finely divided serpentine almost free from

[1] See Geological Magazine, August, 1909, p. 346.

[2] Only the simplest form is here described. For details and figures see Max Eckert, "Das Gottesacker, ein Karrenfeld im Allgäu": Wiss. Ergänzungsheft zur Zeitschrift der D. und Ö. Alpenverein.

vegetation. Except for the presence of some larger rock-fragments, the material may be compared with the loose ash which collects round the crater of Vesuvius, with which, however, as regards origin, it has nothing in common.

The loose powder on the Reckner slope must be constantly carried downward by the melting and falling snows, and to the same extent renewed. We have here a hint of the way in which a rock may disintegrate at the level of the snow-limit, and perhaps under the action of firn, where alternations of frost and thaw play an important rôle.

Older Channels of Upper Tarntal.

The higher and older outlet channels on the west side, by which the Upper Tarntal once drained into the north and south channel (*c*, *d*,[1] Fig. 2), are thickly strewed with erratic blocks of Reckner serpentine. Judging from the amount of demolition and erosion which has been effected since these channels were used, they must have been first formed during one of the older glaciations, or at any rate before the last general advance. But the presence of erratics in these old watercourses implies a movement of ice at a level of 2550 metres, and a corresponding snow-limit above the ice and below the summit ridge; in other words, the snow-line must have made an early stand at 2650 metres nearly. The date of this resting stage could hardly have been later than the close of the Riss period or the first advance of the Würm glaciers. Since the serpentine blocks were left in these high channels the rear wall of the Grübl has been cut back by ice, which could only work efficiently as long as the snow-line remained near the level of 2400 metres.

Glacial History.

The history of the Grübl can only be written on the assumption that the snow-line stood on two different occasions at or near 2400 metres, and, again, twice at about 2650 metres. The sequence of events was somewhat as follows:—(1) The older corrie of the Grübl, with the higher floor and the rear wall to west of the present one, was formed during a sojourn of the snow-line at 2400 metres, when the Riss glacier was in retreat. (2) At a later stage of the same glaciation, or in the first forward movement of the Würm, the basin of the Upper Tarntal was excavated down to the level of the higher outlets (*b*), while the snow-line persisted at 2650 metres. (3) During the final retreat, that of the Würm glacier, the snow-line again stood at 2400. On this occasion the floor of the Grübl was lowered and the demolition of the rear wall broke down the connexions at *b* and *d*, as related above. (4) Lastly, a second stand above 2600 metres reduced by 30 metres the floor-level of the Upper Tarntal, the north-west outlet was pierced and subsequently dammed, since which no advance of the ice has taken place.

Incidentally it may be observed that as far as this evidence goes there is no necessity to suppose that the snow-line ever rose above 2650 metres during the interval between the Riss and the Würm period. The climatic snow-line to-day is here at least as high as 2750 metres.

[1] See Map, Fig. 1, p. 245.

The question whether the last stand at 2650 metres was an event in the closing history of the Ice Age as the Daun advance, or merely a recent incident of climatic oscillation, is left undecided.

The level of the snow-line when it stood for a second time over the Grübl may have been somewhat lower than the first stand near 2400 metres; so also the second stand in the Upper Tarntal may have been somewhat under 2650 metres, the new floor in both cases being lower than the old.

The Navis Valley Drift.

The assumption underlying all the above conclusions, namely that snow-line and firn-line coincide, is safe enough as regards the small glaciers of the corries, and is probably not far from the truth in the case of the glaciers taking their rise in the Tarntal Mountain, especially during the retreating stages, when the area covered by firn and snow was never very large. It may, indeed, be doubted whether at so high a level as that of Navis (1343 metres) any glacier-ice was contributed by the firn from the Tarntal during the extreme of the Würm period, when the snow-line was below 1200 metres at the northern border of the Alps.

On the evidence of erratics from the Central Alps, it has been inferred that the ice-surface in the Inn Valley during the last maximum of cold must have reached a height of 1800 metres or more.[1] The snow-line in these parts could not at the time have been higher than 1200 metres. The significance of the evidence will be considered later. It seems that under circumstances massive ice may accumulate much above the level of the snow-line at the place.

The Inn Valley glacier in this case must have formed a high dam in front of its tributary the Sill.[2] It does not follow from this that the ice in the Sill Valley rose to the same high level. The ice flowing from the Inn up the Sill Valley was retarded by friction and wasted by ablation. It met the Sill glacier at the point at which the two tongues had equal amounts of moving energy. The Navis Valley in turn was dammed by the ice of the Sill, and it is important to determine the height of the ice-surface in this valley during the Würm period.

At a level of 1300 metres, close to the settlement of Navis, are found some blocks of gneiss which could only have been brought by the ice of the Sill Valley (or Wipptal) to which the Navis is tributary. The blocks probably came from the Olperer Alps. They were borne down the Sill tributary in the Valsertal, and were carried by the back flow of the Sill ice into their present position.

I learn from the Pfarrer of Navis, who first called my attention to these blocks, that the stone is in good demand for building purposes, and that one big boulder of gneiss has been quarried completely away. I take this opportunity of expressing my thanks to the Pfarrer, the Rev. Johann Schileo, for this and for much welcome information concerning the topography, many useful names being incorrectly given or omitted altogether on the maps.

[1] A. Penck & E. Brückner, *Die Alpen im Eiszeitalter*, 1907–9, pp. 268, 1143.

[2] See Map, p. 341 of this Magazine for August, 1909. The Sill is the stream shown on the western border of the map, reproduced here on p. 245.

The highest level reached by these gneiss blocks cannot therefore be precisely known. But the valleys of the Klamm and Weidereich brooks which join to form the Navis are hardly accessible enough from the inhabited parts to have been exploited by cottagers in search of stone, and it is unlikely that the Sill erratics were carried much above the level of Navis even during the period of extreme glaciation to which their transport is to be referred.

In the Klamm Valley, just above Navis at about 1400 metres, is a conspicuous bar of moraine material, so little above the point reached by the crystalline erratics that it may well mark the site at which the Klamm Valley glacier was met by the back-flow of the Sill ice. It is, however, more likely that this is the end moraine which was formed by the Tarntal ice-tongue during a retreating stage of the Würm, at which time it may be supposed that the Sill ice was also in retreat. In either case the ice-surface could not have stood much higher than 1500 metres. The valley drift which in a measure determines cereal cultivation does not reach above 1600 metres, and may belong in part to an older glaciation.

In one part of the Navis Valley, on the north side near the Wetterkreuz at 2151 metres, there is a marked change in the surface gradient, the slope being much steeper below the Wetterkreuz than above it. If this ledge is the rim of an ice-trough it most likely belongs to one of the earlier glaciations, when the floor of the valley and the snow-line were both higher than they were during the latest, the Würm glaciation. But the gently sloping floor above the Wetterkreuz may be accounted for as a plain of nival denudation, the 'Abtragungsebene der Schneegrenze' of Richter.[1] The masses of moraine material above 2200 metres which accumulated during the persistence of the 2400 metre snow-line make this explanation the more acceptable. Taking all the evidence together, it appears most improbable that the ice-surface was at 2100 metres when the Schafseiten corries were last occupied by ice, or even when they were first formed, supposing them to have been more than once filled with ice.

Of the four resting-stages which have left their traces in the Tarntal district two may be doubtfully correlated with Glacial periods recognized elsewhere.

The bar or 'Riegel' at 1400 metres in the Klammbach may be the equivalent of the moraine deposits above Trins in the Gschnitztal, the 'Gschnitzstadium' or γ stage of Penck. The Trins glacier rising in the high ground of the Stubaital Alps would naturally end at a lower level than the glacier of the same date in the Navis Valley with a much smaller feeding-ground. It should, however, be noted that the terminal moraine of the γ stage is placed by Penck at the mouth of the Navis Valley.[2] The post-Würm snow-line of the Grübl at 2400 metres would appear to be somewhat higher than that of the γ stage of this valley, to which Penck assigns a level of 2100 metres. For the Gschnitztal the snow-line of the γ stage is fixed at 2300.

[1] E. Richter, "Geomorphologische Studien in den Hoch-Alpen": Petermann's Mittheilungen Ergänzungsheft, 1900, vol. cxxxii, p. 77.

[2] Penck & Brückner, *Die Alpen im Eiszeitalter*, 1907–9, p. 343.

On the analogy of the present nival gradient the ancient snow-limit in the Navistal should have been lower than in the Gschnitztal.

The latest post-Würm stand recognized in the Tarntal at about 2650, certainly not lower than 2600 metres, represents a depression below the present snow-line of about 150 metres. It may turn out to be the equivalent of the Daun stage, when the snow-line is supposed to have been lowered to the extent of 300 metres.[1]

The two pre-Würm stages of the Tarntal with snow-lines at 2400 and 2650 metres respectively cannot be identified with any of the stationary periods hitherto recognized.

Definition: 'Nival Plane' and 'Nival Gradient'.

In the discussion which follows account must be taken of the contemporary variation in the height of the snow-line in different parts of the Alps.

The small map compiled by Hess[2] from a great number of observations shows the present snow-line near the central ridge some 800 metres higher than that on the border of the region now covered by snow.

The imaginary surface containing all the different snow-lines of the same period may be called the 'nival surface', or more simply 'nival plane'. The latter term is sufficiently appropriate to present conditions; the rise of the snow-line over considerable spaces being, as Hess's map shows, nearly proportional to the horizontal distance. The angle made with the horizon by the nival plane is the 'nival gradient'.

Use of Maps in tracing Ancient Snow-lines.

In order with the help of maps to trace over a wider area the extension of the snow-line during any one stationary period, it is necessary to know for each stage the orientation of the nival plane; only in this way will it be possible to sort correctly into their respective groups all the traces of the several nival surfaces.

The snow-line in the Alps of to-day is, as we have seen, found to rise as much as 600 or 800 metres as the axial ridge is approached from the border of the snow-covered district. The change in level is no doubt mainly due to variation in the amount of annual precipitation, the belt of maximum rainfall being in places as low down as 1800 metres,[3] seldom much above 2000 metres.[4]

It cannot on *a priori* grounds be assumed that the zone of maximum precipitation stood at the level at which it is found to-day, or that it varied according to any definite rule with reference to the position of the nival plane. It has, however, been inferred from the heights of corrie-floors and other evidence that the snow-lines of previous cold periods ran on slopes approximately parallel with that of to-day.[5]

[1] Penck & Brückner, *Die Alpen im Eiszeitalter*, pp. 348, 635.
[2] H. Hess, *Die Gletscher*, 1904, p. 74.
[3] Ibid., p. 44.
[4] J. Hann, *Handbuch der Klimatologie*, 1908–10, p. 258.
[5] A. Penck & E. Brückner, loc. cit., p. 1144. E. Richter, *Gletscher der Ostalpen*, p. 277 (quoted by Penck).

Karwendel Gebirge.

Professor Rothpletz has called attention to the corries[1] of the Karwendel Gebirge, and much can be learnt from his work[2] and the large scale-map which accompanies it.

Interpreted according to the method here used, the corries of the outermost chains of the Karwendel give evidence of one or two snow-lines at a lower level than those observed in the Navis district. The Great Soiernkessel on the north side of the ridge is a characteristic corrie. The floor at 1546 metres is marked by a lake with a dam of standing rock.[3] The ridge at the back bears several summits higher than 2000 metres, the highest, the Soiernkarspitz, reaching 2260 metres. This indicates a long stand of the snow-line in the neighbourhood of 1700 metres.

The Krapfenkar and Mondscheinkar, also in the 'Vordere Karwendelkette', have floors at 1700 or 1800 metres, under ridges of 2100 metres, indicating a stand of the snow-line at 1850 metres nearly. The floors appear to be ill-defined, and the stand in question is probably to be referred to one of the older glaciations. The higher lake of the Soiernkar at 1836 metres may belong to this stage.

In the 'Hintere Karwendelkette', south of the last-named ridge, are several corries with floors at 2100 to 2300 metres. The summits on the ridge reach heights of 2550 to 2750 metres. This requires a snow-line at 2350 metres or higher. These corries may be companions of the Grübl and Schafseiten group of the Navistal.

Traces in other parts of the Alps of the 2650 metre snow-line should be sought in the first instance on ridges of the same height as the Tarntaler Köpfe (Reckner, 2891 metres) and at the same distance from a high snowy range as Tarntal is from the Olperer.

About 3 kilometres south of the Sonklarspitze in the Stubaital Alps is a ridge of the required height. Several summits reach 2880 metres, and one, the Scheiblehner, rises to 2991 metres. Just below is a large lake, the Schwarzsee, 2548 metres above sea. This lake-basin may well be a contemporary of the corrie of the Upper Tarntal. The above details are taken from the Austrian General-stabskarte, Sheet Sölden.

The Scheiblehner is nearer to the Central Alps than the Tarntal, and according to analogy the corresponding snow-line should be somewhat higher. More precise determinations of levels may show this to have been the case.

Denudation under Firn and Snow.

On the slopes of snow-covered mountains there must be a belt of the land surface at which the frequency of the oscillations of temperature about the freezing-point of water is a maximum. (Here

[1] The corrie is a feature which gives the motive for topographical names. The equivalents for 'corrie' in other languages will be useful. They are: Welsh *cwm*, Norwegian or Danish *Bodt*, pl. *Bodter*, German *Kar*, pl. *Kare*, also *circus*, French *cirque*, Spanish *hondon*, Indian (Quecha) *cuchu*: the last two names are used in the Equatorial Andes (W. Reiss). W. Reiss & A. Stübel, *Das Hochgebirge der Republik Ecuador*, 1902, ii, p. 164.

[2] A. Rothpletz, *Das Karwendelgebirge*.

[3] Ibid., p. 71.

the surface under the ice-tongue is not considered.) This zone does not necessarily coincide with the snow-line; it is to be sought near the isotherm of 0° C. of mean annual temperature, which in the Alps is probably above the snow-line.[1] It may be that the standing rock under the firn is subject to frequent alternations of the kind in question; the changes may then be determined by variations of pressure and other causes only indirectly dependent on the temperature of the air; the freezing-point under a heavy cover of firn may be other than zero Centigrade.

Above the zone indicated the oscillations of temperature about freezing-point diminish in frequency with the height, for not only is the mean annual temperature reduced, but the range of temperature-variation is narrowed in ascending,[2] and if denudation still goes on it must be due to other causes.

It might be expected that a study of the volcanic cones which project above the snow-line would throw light on the question whether a cover of firn serves to protect the land surface. From the observations of E. Richter[3] in the Alps, I. Russell[4] on Mount Rainier, W. Reiss[5] in Ecuador and Colombia, it seems clear that the glaciers at the snow-line are the most active agents of destruction. According to Russell the work of demolition goes on with the greatest activity along the crevasses which form at the firn-line. The beds of the glaciers are continually receding, with the result that, to use Richter's phrase, the mountain is ultimately beheaded at the snow-limit.

The outlines of extinct volcanoes which have been long subject to this levelling action are well shown in Hans Meyer's photographs of Sincholagua and Quilindaña.[6] In the latter figure the plain of nival denudation is especially conspicuous. The sketches given by A. Stübel,[7] preserving, as they do, the correct relation between vertical and horizontal dimensions, are also instructive.

Russell[8] maintains that above this zone of rapid disintegration the ground is protected by the snow and firn, especially at higher levels, where the snow retains the powdery form until it is removed by the wind or falls to lower levels.

Admitting the facts, the proof that a cover of firn or snow retards erosion is still incomplete. In estimating the comparative rates of erosion all the variables must be taken into account, for example—

(1) The amount of precipitation varies with the height above sea. It reaches a maximum in the Alps at 1800 to 2400 metres, and above this level diminishes with the height. In other regions, with average rainfall, this maximum is accordingly to be looked for at levels below the snow-line.

[1] See J. Hann, *Handbuch der Klimatologie*, p. 268. In the Eastern Alps near Innsbruck the temporary isotherm 0° C. is below the snow-line only during the winter months.

[2] H. Hess, loc. cit., p. 41.

[3] E. Richter, *Geomorphologische Studien in den Hoch Alpen*.

[4] I. C. Russell, "The Glaciers of Mount Rainier": U.S. Geol. Surv. Reports for 1896–7 (1898), vol. xviii, p. 382.

[5] W. Reiss & A. Stübel, *Das Hochgebirge der Republik Ecuador*, 1902, ii. pp. 165, 173.

[6] Hans Meyer, *In den Hoch-Anden von Ecuador*, Berlin, 1907.

[7] *Die Vulkanberge von Ecuador*, p. 107.

[8] I. Russell, loc. cit., p. 382.

(2) On slopes at lower levels, where local precipitation is reinforced by the flow from above, the activity of water must be greater than on the high ridges which receive only the snow or rain falling directly on them.

Relation of the Corrie-floor to the Snow-limit.

In general, reliable evidence for any one stand of the snow-line will be found on suitable slopes under ridges which rise only a few hundred metres above the snow-limit. This is the condition for the formation of corries. In such cases the ice-tongues will be short, the firn-line will coincide with the snow-line.

Under higher ridges the ice-tongues of the same period will be longer, the beds will be in the form of troughs rather than basins. In still higher ground the beds of glaciers belonging to successively higher snow-lines will join to form a continuous groove, which gives no indication of a stationary period.

Further, low ridges too near the centres of glaciation will be whelmed in ice from the high ground. Corries will thus be formed only near the border of the tract for the time being under glacial conditions, the different stands of the snow-line will leave their traces on successively higher ridges nearer the centre, the lowest corries corresponding to maxima of cold being on the extreme border of the area occupied by ice. Such is, in fact, the distribution of corries actually observed.

All pronounced corries are held to bear precise and unequivocal testimony to some one stand of the snow-line, during which the ice just filled the hollow. None of this evidence can be neglected. Corries with moraine dams must have been filled with ice during the latest retreat, the loose material being unfitted to withstand the thrust of moving ice of any later advance.

The basin-like hollow of the corrie is the counterpart of the trough occupied by the long glacier tongue. Amphitheatres with ill-defined floors are either the sources of longer ice-streams or are the walls of ancient corries, the floors of which have been broken down by a subsequent advance of the ice.

This explanation of the origin of corries differs somewhat from those hitherto in use. The site of the corrie was determined by the height of the snow-line, the height of the ridge, the catchment area, the conditions of precipitation and insolation on which depended the length of the ice-tongue. A watercourse or groove led the firn in the required direction. There was no other marked hollow. Where several corries are found at nearly the same level it cannot be supposed that each was determined by a pre-existing pit or funnel.[1] The formation of corries is not limited to extremes of glaciation. At the time the corrie was formed the snow-line was not on the level of the floor,[2] but considerably higher. The level of the corrie-floor is in no way related to the level of the ice-surface in the main valley to which the corrie-watercourses were tributary.[3]

[1] See James Geikie, *The Great Ice Age*, 1894, p. 237.

[2] See Böhm, *Die alten Gletscher der Mur und Mürz*, 1900, p. 19; also Richter, *Geomorphologie*, pp. 15, 75.

[3] See Penck, *Die Alpen im Eiszeitalter*, p. 285.

If the views here set forth be correct, the lip of the corrie marks the lower end of the ice-tongue under which the basin was excavated; the boundary of the glacier is defined by the lip and the watershed of the catchment area above it. By means of these data some precision could be introduced into the computation of the corresponding snow-line. Brückner[1] has found that about one-third of the whole surface covered by a glacier belongs to the tongue; thus the contour-line which marks off the lower one-third portion from the upper two-thirds of the glaciated area is the snow-line. Where contoured maps on a large scale are available, a rule such as this, though empirical, should give good results in the case of corries, the areas dealt with being small.

Erosion under the Ice-tongue.

The direct action of glacier-ice in wearing and scouring the standing rock is here accepted as an established fact. It has not been thought worth while to qualify the terms in which this postulate is implied. For the purpose of this paper, however, it would suffice to assume merely that the bed of a glacier tongue differs distinctly in form or dimensions[2] from that of a channel eroded by running water alone. The truth is that all conclusions hitherto drawn regarding the relative rates of erosion by ice and by water are of doubtful validity. The two processes cannot be observed apart.

The facts to be taken into account are—

The glacier tongue being below the snow-line, where all the snow that falls within the year melts within the year, the whole of the local precipitation must reach the land surface under the ice as running water by the numerous clefts which form at the firn-line and below it. Generally, however, the channels in the ice deflect the water, which thus reaches the bed not at the point directly under the spot at which it falls, but lower down the valley.

Some snow above the firn-line melts and reaches the bed to form part of the stream. The snow-line is only the limit at which the falling snow just balances the melting snow.

The whole of the glacier-ice is contributed by the firn, that is, by a part of the precipitation above the snow-line. By ablation this all joins the stream at various points above the lower end of the ice-tongue, so that the water running out at the ice-portal during the year is exactly what with the same amount of precipitation would flow over the bed at this place if no glacier existed.

The glacier-bed is a water-channel as well as an ice-channel; the form taken by the bed is due to the combined action of water and ice.

Gradient of Glacier-ice.

The gradient of the ice surface during the last maximum of cold has been inferred from a great number of records by various observers

[1] Brückner, *Meteorologische Zeitschrift*, 1887, p. 31. Hess, *Die Gletscher*, p. 74. The ratio actually observed diverges widely in extreme cases from Brückner's mean. Richter holds that the proportion of glacier-ice to firn is, as Brückner himself hints, more nearly 1 : 4 than 1 : 3 (E. Richter, *Gletscher der Ost-Alpen*, 1888, p. 41). Hess adopts the ratio 1 : 3·1 (loc. cit., p. 83).

[2] See A. Penck, "Uebertiefung der Alpentäler": Internat. geogr. Congress, 1899, p. 239.

who have noted the highest occurrences of ice scratches and erratics in different parts of a valley.[1] In the application of this method some caution seems to be necessary. On the analogy of present conditions and on the ground of direct observations, it may be admitted that the nival gradient was, at least in the higher ground, always as steep as it is to-day. It is perhaps not out of the question that massive ice formed above the snow-line even in the high ground. But if the rise in the snow-line was due to diminished precipitation it is difficult to suppose that the firn-line stood very much higher than the snow-limit. Even assuming for the maximum of cold a somewhat steep nival gradient and a firn-line high above the snow-line, it can hardly be doubted that ice would form at successively higher levels during the retreat. The highest scratches may thus belong to milder periods; so too the highest boulders in ground near the centre of glaciation.

The highest crystalline erratics in the neighbourhood of the Alpine foot-hills no doubt belong to a period of extreme cold, but not necessarily to the last maximum; boulders of earlier glaciations might persist for an indefinite time if landed between the tributary water-courses on shoulders and spurs where they would not be disturbed by the ice of a subsequent advance.

The inclusion in the estimate of boulders and scratches belonging to retreating stages would give for the maximum an ice-gradient steeper than was actually attained in the higher parts of the valleys. To include in the estimate boulders which were landed during some older glaciation when the valley-floor was higher would lead to false conclusions as to the thickness of the ice in the lower reaches of the valleys.

Relation between Nival Plane and Zone of Maximum Precipitation.

The hypothesis that the rise in the snow-limit is mainly the result of diminished precipitation in the high ground leads to some interesting deductions concerning the relation between nival surface (N.S.) and belt of maximum rainfall (M.P.). At the present time the nival

Fig. 3. Diagram showing break in the nival gradient when the nival surface passes through the zone of maximum precipitation.

surface (N.S. 1, Fig. 3) on the northern slopes of the Alps is nearly a plane,[2] all parts of which are above the zone of maximum rainfall.[3] With these conditions as a starting-point we may consider the following hypothetical cases:—

Case 1. If while M.P. remains stationary N.S. is depressed continuously, it takes up successive positions as N.S. 2, nearly

[1] Penck & Brückner, *Die Alpen im Eiszeitalter*, p. 604.
[2] See Hess's map, loc. cit., p. 74.
[3] Hess, loc. cit., p. 44; J. Hann, *Klimatologie*, 1905, p. 262.

parallel to N.S. 1, until it falls so low as to pass through M.P., as at C.D. Then that part of the nival surface beyond M.P. will not be in the same plane with C.D., but will be horizontal nearly, or may even rise in the contrary direction if the outer ridges like K. are too small to cause by their own mass a marked increase in the precipitation (Fig. 3). This break will be maintained as the nival surface continues to fall.

Case 2. As N.S. falls M.P. is depressed to the same extent, but the amount of precipitation remains constant. In all the new positions N.S. remains parallel to N.S. 1. The supply of firn in the high ground is much reduced.

Case 3. As in the last case M.P. falls at the same rate as N.S., but the amount of annual precipitation is much increased.

Case 1 seems to be inconsistent with parallelism of the nival planes through all stages of glaciation. Seeing, however, that the zone of maximum precipitation stands in winter at the level of 1000 metres or lower,[1] this difficulty would vanish if it could be shown, as Penck suggests,[2] that during the ice period the precipitation took place mostly in the coldest part of the year. But with this modification case 1 is open to the same objection as the following one.

The hypothesis that N.S. and M.P. rise and fall in company is the most probable one. Case 2 does not, however, provide for a supply of ice sufficiently copious to fill the lower reaches of the valley up to or even above the level of the local snow-line, as seems to have happened in the Inn Valley during extremes of cold.[3]

It remains to consider whether case 3, which would account for some of the most salient facts of Alpine glaciation, is admissible.

EXPLANATION OF PLATES.

PLATE XIX.

FIG. 1. Corries on the north slope of the ridge between Schafseiten Spitz (2604 metres) and Bendelstein (2422 metres). From a point on the slope of the ridge east of Mieselkopf, distant about 6 km. Looking south.

FIG. 2. The horizontal surface a little above the middle line of the picture, probably a plain of nival denudation, is held to indicate a former level of the floor of the Grübl. View taken from a point about 2100 metres above sea on the slope under the Schoberspitz, distant about 1 km. Looking south-east.

PLATE XX.

FIG. 3. Wall of serpentine blocks forming an almost complete girdle round the Reckner ridge at a level of 2600 metres and upwards. From a knoll in the Upper Tarntal 2600 metres above sea, distant about 0·75 km. Looking south-east.

III.—NOTES ON NEW OR IMPERFECTLY KNOWN CHALK POLYZOA.

By R. M. BRYDONE, F.G.S.

(PLATE XXI.)

(*Continued from the April Number*, p. 147.)

MEMBRANIPORA WOODWARDI,[4] nov. Pl. XXI, Figs. 1–3.

Zoarium free or adherent, always unilaminate.

Zoœcia large, subpyriform, with broad margins sloping slightly inwards and expanding at the foot into a short front wall; areas

[1] J. Hann, *Handbuch der Klimatologie*, 1905, p. 262.

[2] Penck & Brückner, loc. cit., p. 1145.

[3] Loc. cit., p. 268.

[4] Dedicated to the Editor.

Fig. 3.—Block-wall under Reckner-ridge. *Bemrose, Collo.*

elliptical, length ·5 to ·75 mm., breadth ·31 to ·45 mm., tapering towards the head, across which stretches a slight internal shelf, which straightens the apparent outline; from the edge of this shelf hangs a stout oval ring, which connects it with the floor of the zoœcium; zoœcial boundaries distinct.

Oœcia very large, almost square; the free edge runs out over the area for a short distance and is then cut back in a curve parallel to the edge of the area beneath.

Avicularia subvicarious, forming the initial zoœcia of new rows; they are practically small and narrow zoœcia pinched together at the top into a beak and spanned slightly below the middle of the area by a very slender bar, of which only the broken ends are usually preserved; in the immature stage found in the *M. cor-anguinum* zone this beak is very short and markedly unsymmetrical, in the higher zones it is greatly produced and nearly or quite symmetrical.

Found occasionally in the zones of *M. cor-anguinum* and *Marsupites*, and freely in the zone of *Act. quadratus* in Hants and in the zone of *M. cor-anguinum* at Gravesend.

MEMBRANIPORA CORALLIFORMIS, nov. Pl. XXI, Figs. 4 and 5.

Zoarium adherent, sometimes tuft-shaped, but very generally forming long narrow bands.

Zoœcia elliptical, very small; length of area ·24 to ·3 mm., breadth ·15 to ·2 mm.; primarily they are quite simple, but along the walls of mature zoœcia there forms a thick, continuous, smooth incrustation pierced by numerous short tubes, giving it a madreporiform appearance; the tubes show a weak tendency to regularity of occurrence, there being usually a pair, one on either side of the upper part of the area; this incrustation may overhang the area or recede from its edge, which can then sometimes be seen to be studded with tiny perforate tubercles; the incrustation often envelops the oœcium, leaving only the aperture distinguishable. Among the tubes may be sometimes found miniature avicularia.

Oœcia globose, free edge curved inwards.

Avicularia vicarious, rare except along the edge of zoaria, wide at the head, and tapering towards the foot, close to which they are spanned by a slender bar, of which, as a rule, the broken ends alone are preserved as a slight constriction of the outline; the broad elliptical aperture is coterminous with the walls in the lower part, but in the upper part is surrounded by an internal shelf.

Found in the zone of *M. cor-anguinum* at Gravesend (abundantly) and in Hants.

PSEUDOSIEGA, gen. nov.

Diagnosis.—A genus of Membraniporidæ in which a secondary zoœcial layer is formed over and arising out of a layer of ordinary Membraniporidan zoœcia.

This genus seems to be analogous among the Membraniporidæ to *Steginopora* among the Cribrilinidæ. The secondary layer apparently arises from the walls of the primary layer, and if so the essential

difference between *Pseudostega* and *Membranipora coralliformis* is little more than one of degree.

PSEUDOSTEGA CANTIANA, nov. Pl. XXI, Figs. 6 and 7.

Zoarium adherent.

Zoœcia in the lower layer fairly large; length of area ·3 mm. breadth ·2 to ·22 mm.; in the upper layer they have only vaguely defined outlines and are very variable in minute details, but are very uniform in general structure; they run in very straight and regular alternating rows, in which, after the initial zoœcium, all have a large area, with a stout denticle projecting into it at the foot and directed slightly downwards, and, as a rule, a small curved indentation opposite to it at the head, possibly representing the aperture of an immersed oœcium; across the area stretches a broad bar, shaped like a very shallow V pointing downwards, which divides the area into two compartments, of which the lower is the smaller and is reduced by the point of the V and the marginal denticle to the shape of an eight lying on its side; at the foot the area is overlooked by two tubular prominences on the marginal wall separating it from the area of the preceding zoœcium; these might naturally be taken to represent two avicularia of the preceding zoœcium uniformly present in the lower layer, but I cannot find any traces of paired avicularia being regularly present there, the nearest approach lying in the tiny paired slits which can be seen at the head of some of the zoœcia of the lower layer in Fig. 7, a figure of the only specimen in which the lower layer is exposed except at the very edge of the zoarium. The initial zoœcium of a row has the point of the V directed upwards and a denticle projecting from one side of the upper compartment; the lower compartment is much reduced and irregular in shape, and there is a single tubular prominence at the foot. This general system is much obscured by crowding in the early stages of the zoarium, but is remarkably regular in the later stages.

Rare in the *M. cor-anguinum* zone at Gravesend and Chislehurst. *Reptescharipora rustica*, D'Orbigny, by its general appearance should be closely related to this species, but as Canu [1] makes it a *Steginopora* it must be assumed to have a Cribriline lower layer.

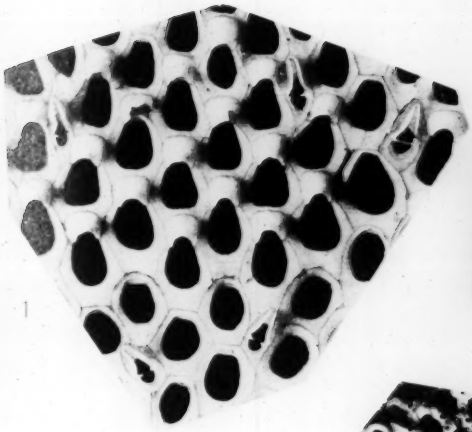
EXPLANATION OF PLATE XXI.

(All figures × 12½ diam.)

FIG. 1. *Membranipora Woodwardi*, zone of *Act. quadratus*, Hants.
,, 2. Ditto, zone of *Act. quadratus*, Hants. Lighted to show up the interior of the zoœcia.
,, 3. Ditto, zone of *M. cor-anguinum*, Gravesend.
,, 4. *M. coralliformis*, zone of *M. cor-anguinum*, Gravesend.
,, 5. Ditto, zone of *M. cor-anguinum*, Gravesend. From the tip of a large branching zoarium.
,, 6. *Pseudostega Cantiana*, zone of *M. cor-anguinum*, Gravesend.
,, 7. Ditto, zone of *M. cor-anguinum*, Gravesend. Lower layer in focus, upper layer rather out of focus.

[1] Bull. Soc. Géol. France, 1900, p. 456.

(*To be continued.*)



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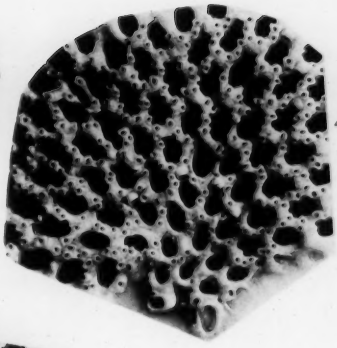

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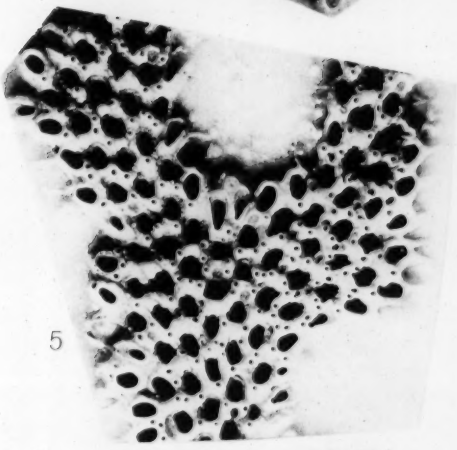

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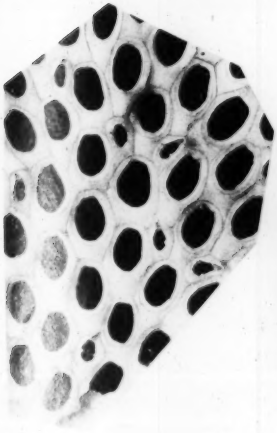

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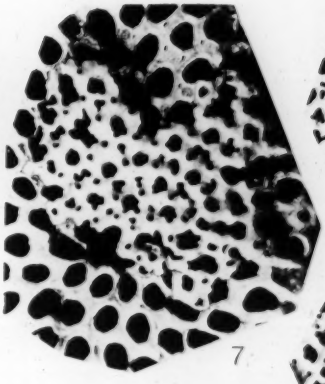

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IV.—On the Systematic Position of the Upper Cretaceous Dinosaur *Titanosaurus*.

By Baron Francis Nopcsa.

BEING prevented by other work from continuing at present my work on the Danian (Laramie) Dinosaurs of Transylvania, I wish briefly to draw attention to the fact that the Upper Cretaceous *Titanosaurus*, as known from the Montagne Noire in France and from the Cretaceous formation of Argentina, and perhaps also from East Africa (as already pointed out by Fraas), has nothing to do with the Sauropoda, but belongs to the Trachodontid Orthopods, as proved by the abundant Transylvanian material at my disposal.

Without attempting to enter at present into the question of generic identity of the American, African, and European Upper Cretaceous Titanosaurs, I wish to point out that the Montagne Noire and the Transylvanian Reptiles are generically identical and must be known as *Telmatosaurus*, the name *Titanosaurus* being only applicable to the English Wealden Sauropod described in 1887 in the Quarterly Journal of the Geological Society. The striking survival of a Sauropod so late as the Danian may therefore be questioned, and the time-table in that most interesting recent paper "Distribution and Range of Dinosaurs", by Professor R. S. Lull, must therefore be modified accordingly.

The *Telmatosaurus*, to the tail of which the '*Titanosaurus* vertebræ' belong (as proved by Transylvanian undescribed material), is a heavily built Trachodontid animal, with a straight Stegosaur-like femur (small fourth trochanter), a heavy and relatively strong humerus, nearly solid bones, and probably *quadrupedal* locomotion. Being the only Iguanodontid animal which we can suppose to have secondarily descended on its fore-legs (as *Stegosaurus*, etc., had done after passing a *Scelidosaurus*-like stage of evolution), *Telmatosaurus* deserves special attention. Since *Telmatosaurus* is accompanied in Transylvania by another Dinosaur (*Mochlodon*) which, according to its degree of specialization, would rather correspond with the Lower Cretaceous than with the Danian, and since the same is also true of the *Telmatosaurus* itself (see Sauvage's remarks on *Telmatosaurus* = *Limnosaurus* in *Rev. Crit. de Palæozoologie*), the Dinosaurian fauna of Transylvania bears the same relation to the American Laramie fauna as the recent fauna of Australia to that of the recent fauna of the rest of the world.

V.—The Geology of the Dolgelley Gold-belt, North Wales.

By Arthur R. Andrew, M.Sc., F.G.S.

(*Concluded from the May Number*, p. 211.)

Bryn-y-groes Lode.—About 500 yards east of the Clogau lode, there is a parallel lode which has been worked for copper. Striking 50° east of north, its outcrop may be traced for about 1½ miles; its width is very variable. Chalcopyrite and pyrites and a little gold are present in the quartz. The lode is confined to the Vigra Beds,

and running with the beds, it is associated throughout its length with greenstone sills.

Bryntirion Lode.—East of the Bryn-y-groes lode is another parallel lode, with, however, a strong dip to the south-east. Like the Bryn-y-groes lode it is poorly mineralized, and has been worked but little. It is confined throughout its length of three-quarters of a mile to the Vigra Beds, and it is but seldom associated with the intrusive greenstones.

Garth-gell Lode.—At its northern end this lode crosses the junction of the Afon Cwm-Mynach and the Nant-Cesailgwm, and from there it has been traced 200 yards to the south. Its strike is 25° east of north, and its dip vertical. It traverses the Vigra Beds all the way, and is associated with small greenstone sills and dykes. Throughout its length its width is very variable. In many places it has clay selvages along its walls, but these are not constant. The quartz of the vein is hard, white, and often drusy; pyrites and chalcopyrite are the most frequent minerals, and with them also are found blende, some galena, muscovite, and chlorite. In 1900, 26 tons of quartz were milled for 5 ounces of gold.

Maes-tryfer Lode.—This is an unimportant vein which crosses the line of the Garthgell lode close to the junction of the Cwm-Mynach and Cesailgwm streams. Different from all the lodes already described, its strike is no longer north-easterly, but 30° south of east. It courses through the Vigra Beds, and is confined to very near their junction with the Clogau Slates. Little work has been done on the lode, and its characters are not known.

Cambrian Lode.—300 yards above the point where the Afon Cwm-Mynach enters the estuary, the outcrop of a quartz lode is seen in the stream. It courses in a north-east and south-west direction (65° east of north) and can be continuously traced for about half a mile. It is vertical throughout its length; its walls are well defined, and in places have selvages of clay, 2 or 3 inches thick. The vein is poorly mineralized, the chief minerals which do occur being galena, chalcopyrite, and blende, for the first of which the lode was once worked. The lode crosses the Vigra Beds of the Maentwrog Series.

The Voel Group of Lodes.—About the year 1860 there were several companies mining different portions of the lodes of this group, each mine being known by a distinctive name, Princess Alice, Prince of Wales, Glan-y-morfa, and Moel-Ispri. Later (1900–4), these lodes were worked by the Voel Company. There are three separate parallel lodes on the property with numerous small stringers. The strike of the lodes is north-easterly, changing from 70° east of north on top of Foel Ispri, to 50° east of north near the turnpike road. The most southerly of the parallel veins (that nearest to the estuary) has been opened up in several places, and has a shaft extending below sea-level. The lode is from 1 to 3 feet wide, with clearly defined walls. The quartz contains a large amount of blende, along with some chalcopyrite, pyrites, and pyrrhotite.

The intermediate lode of the three cannot be clearly seen; it is opened up by a few cross-cuts into the side of the hill, but these are no longer accessible. The uppermost and most northerly of the Voel

lodes dips usually to the south, but in places towards the north the lode is seldom less than 3 feet in width, often much more. Leaders and stringers are frequent, but otherwise the walls are well defined. The blende in this lode is abundant; galena and chalcopyrite also occur. The Moel-Ispri Mine (the Voel C lode) mined 66 tons of quartz for 88 ounces of gold, while the Prince of Wales Mine (the Voel A lode) has mined 20 tons of quartz for 63 ounces of gold. The outcrop of the Voel C lode may be traced for about 1 mile; at its western end it strikes 70° east of north; towards the east it strikes more and more northerly, finally becoming 40° east of north.

The two most southerly lodes of the Voel group occur in the Pen Rhos Beds; the most northerly runs along in the Vigra Beds for most of its observed length, but finally at its eastern extremity enters the Pen Rhos Beds. Greenstones occur frequently along the course of the veins, and the latter are most clearly defined in the neighbourhood of an igneous intrusion.

Cesailgwm or Wnion Lode.—This lode is well exposed on the slopes of the hill east of Cesailgwm-mawr, about 1½ miles up the stream which enters the Mawddach estuary near Borthwnog. Thence it may be traced at intervals for a distance of two-thirds of a mile to the west, and for a distance of about 2 miles to the east. Its general strike is 60° east of north, its dip never varies very much from the vertical. Its walls are well defined and consist of the Clogau and the Vigra Beds, near whose contact the lode always lies. Intrusive rocks occur at intervals along the course of the lode. The lode is usually 2 to 4 feet wide, often dwindling down, however, to mere veinlets. The vein is not heavily mineralized, but blende, galena, and chalcopyrite are found. In the years 1893–4 this lode produced 36 ounces of gold from 61 tons of stone.

In the Cesailgwm Valley, there is a lode parallel to and north of the Cesailgwm lode, which has been worked by the Borth Valley Gold Mining Company. Where opened up the lode formation is about 4 feet wide; it has a banded structure, being made up of 2 feet of poorly mineralized quartz, and a varying thickness, up to 2 feet, of mingled quartz and crushed country rock. Few mineral sulphides are to be seen; gold can be got by crushing and panning. This lode yielded 27 ounces of gold in 1906.

Blaen-y-cwm Group.—To the north of Blaen-y-cwm, near the head-waters of the Afon Wnion, there are numerous outcrops of small lodes, none of which extend far in strike. There are five lodes of this nature, all occurring in the Clogau Beds, though some extend from there into the Vigra Beds. Two of these lodes strike 60° east of north; two strike 15° south of east; one strikes 15° east of north.

All the veins of this group are similar to each other in formation and contents. Their width ranges from 3 feet downwards. The walls of the vein are poorly defined and usually there is no selvage of clay. The intrusive greenstones are seldom seen in association with this group. The lode matter contains a large admixture of shaly material derived from the walls; the quartz contains galena, blende, arsenopyrite and pyrites.

Cefn Coch Lode.—Next to the St. David's–Clogau and the

Gwyn-fynydd lodes, this is the most important lode in the Dolgelley belt. On the slopes of Cefn Coch Hill, and to the north-east, it strikes 45° east of north; to the south-west the strike becomes more northerly (25° east of north) for about half a mile; then on the slopes of Foel-ddu the lode regains its original strike; the total traceable outcrop amounts to about 2 miles.

Through the greater part of its length, the lode runs along the contact of the Clogau Slates and the Gamlan Shales. The topmost bed of the Gamlan group is here a coarse-grained quartzose grit, and at times the lode is represented by a series of stringers ramifying through this grit. Westward over the shoulder of the Cefn Coch Hill, the lode lies mostly in the Gamlan green shales and grits. Greenstone sills occur at intervals along the course of the lode and form one or both walls. This lode has been cited by earlier writers, e.g. Ramsay (12–15), as an instance of a vein forming the continuation of a greenstone dyke, but I have not been able to see anything more unusual than the pinching out of the lode close to a greenstone sill. The Cefn Coch lode branches frequently and is accompanied by parallel veins. The dip of the lode is towards the north-west, so that it very soon becomes confined to the Gamlan Beds below the surface. Its width varies from 6 inches up to 3 or 4 feet, occasionally swelling out into massive blebs of quartz, 10 to 12 feet thick. No clay selvage is present in the lode.

The quartz of the lode is not well mineralized, though the parts already worked out probably contained a much larger proportion of mineral than those now exposed. The most usual minerals in the quartz are blende and galena, and there are also chalcopyrite, pyrites, zincite, and gold. An analysis of the gold from this lode gave the following result: gold, 76·40 per cent.; silver, 22·70 per cent. Between the years 1863 and 1903, though the work has been of a most intermittent character, 2310 tons of quartz have produced 1193 ounces of gold.

Cae-mawr Lode.—This lode is seen on the hills on the western bank of the Mawddach near its confluence with the Afon-wen. The lode has little extent in strike; it strikes 15° south of east, and dips to the south at an inclination of 40° to the vertical. It intersects the Pen Rhos Beds of the Maentwrog, where its walls are clearly defined; the lode is wide, from 8 to 15 feet across. The metallic mineral contained in the quartz of the lode is of small amount and consists of chalcopyrite alone. In 1891 development work on this lode produced 10 tons of quartz for a return of 1 ounce of gold.

Dol-y-clochydd Lode.—Opposite the Precipice Walk, on the crags that overhang the Dolgelley–Trawsfynydd road, outcrops of white quartz have been opened up by a cross-cut. The lode can be traced satisfactorily only for the extent of the greenstone sill in which the cross-cut is driven, but a few isolated outcrops probably mark a continuation along the line of lode beyond the sill. The quartz of the lode contains some chalcopyrite; its strike is 45° east of north. The lode and its accompanying greenstone sill lie among the Pen Rhos Beds, while the isolated quartz outcrops range up into the lower part of the Ffestiniog group.

Glasdir Lode.—This lode has been worked extensively for copper, and like so many of the other copper veins of the district, it has been found to contain gold in addition. The lode is situated on the hills on the eastern bank of the Mawddach below its confluence with the Afon-wen. The lode is confined to the lower part of the Ffestiniog Flags, and its extension in strike is apparently limited. At the main workings the lode courses in a north-east direction, but its whole observed length of outcrop is not more than 100 yards. At the west end the lode appears to pinch quite out, and at this point a thin quartz-vein, running north and south, cuts across it; this vein has been worked a little, but is very barren. West of the quartz-vein, and running parallel to it, a large wide cross-course or fracture cuts the line of the main lode, and has smashed up the rocks for quite 80 yards; to the west of this, the main lode is lost.

The main lode is usually vertical, and its dip, though variable, is always great. It differs from all the other veins of the country in the almost entire absence of quartz. A good section is seen where the main cross-cut is driven to intersect the lode. Looking north-east, we see—(1) on the right, a fault-plane about 1 foot wide in which the country rock is much broken up and comminuted to pug and clay; (2) about 20 feet of green flags and shales, bent about, distorted, and slickensided. These flags and shales are impregnated with chalcopyrite to such an extent that they have been mined for some years for copper; the average tenor of the lode at this level is about 1 per cent. of copper, while in the deeper levels it rises and is said to approach 2 per cent. Blebs of quartz, usually white and poorly mineralized, occur throughout the impregnated flags, but they have no definite arrangement. In places the width of the impregnated zone or lode is as much as 50 feet; it has been opened up considerably in depth, but very little work has been done along the strike.

The deposit has been formed by cupriferous solutions, rising through the fissure on the south-east side of the lode, passing thence into the flags, and there depositing part of their copper contents. It will be remembered that the flags are bent and crushed about, so that they readily allow the passage of mineral solutions, and the diminution of pressure in them would probably facilitate the deposition of the minerals held in solution. The almost total absence of quartz is the unique feature of this lode. Besides chalcopyrite, the only metallic minerals I noticed in the lode were pyrites, bornite, and erubescite. In 1900 this lode produced 199½ ounces of gold. The copper concentrates generally assay about 1 ounce of gold to the ton.

Ffridd-goch Lode.—High up on the eastern bank of the Afon-wen, more than a mile above its confluence with the Mawddach, the Ffridd-goch lode strikes 5° east of north, and dips steeply (70°) to the eastward. It can be traced for about 1200 yards; it is confined throughout to the lower parts of the Ffestiniog Flags. At its southern end the lode runs along and through several greenstone sills, but further north the latter die out. At places the lode is accompanied by one or more parallel lodes. Where it has been opened up it is well defined, and commonly 3 feet in width. The quartz is poorly mineralized, pyrites is the most usual metallic mineral, a little

chalcopyrite and pyrite being also present. Gold was obtained from this lode during the period 1896–1902, 109 tons of quartz being crushed for 105½ ounces of gold.

Ceunant-hyll Lodes.—The Ffridd-goch lode is crossed by the line of the Ceunant-hyll lodes, a set of two or three minor veins on which a small amount of development work has been done. Like the Ffridd-goch lodes these occur in the lower part of the Ffestiniog Flags, and are associated with large intrusions of a coarse-grained greenstone, which is in places amygdaloidal. The largest lode strikes 5° south of east, and can be seen for about 500 yards along the strike; its width is from 18 to 24 inches. There is also another lode, striking 65° south of east, and dipping much more steeply. The vein matter of these lodes is similar, and consists of crumbly pyritous quartz, containing a large amount of talc and chlorite, and a little chalcopyrite; gold also has been found here.

Dol-y-frwynog Lodes.—On the western bank of the Afon-wen, directly opposite the Ceunant-hyll lodes, is the southern extremity of the Dol-y-frwynog lodes. The main lode of these strikes 25° east of north, and has a course of at least 900 yards; it is accompanied by several parallel veins of variable extension in strike, the dip of all being approximately vertical. At the largest cross-cut there are five parallel lodes, ranging from 1 to 6 feet in thickness. To the north another lode has been worked to a great extent; the strike is 35° east of north, and gold was here associated with chalcopyrite and pyrites. The rocks traversed by these lodes are the Pen Rhos Beds of the Maentwrog. Greenstones occur along the course of the lodes, and have their ferro-magnesian constituent largely converted to talc and chlorite.

Cefn-deuddwr Lodes.—At the junction of the Afon Eden with the Mawddach, there are two parallel lodes striking 15° south of east, and dipping towards the north at an angle varying from 55° to 80°. They can be traced for only a short distance, along which they lie in the Vigra Beds of the Maentwrog, and cross in their course several greenstone sills. Chalcopyrite occurs in the quartz, galena and gold also occur in small quantities.

Tyddyn-Gwladys Lode.—About a mile above the Mawddach-Eden confluence, on the road to the Gwyn-fynydd Mine, several old levels and cross-cuts open up the Tyddyn-Gwladys lode; this strikes about 55° east of north, and dips from 60° to 80° towards the north-west. The outcrop of the lode lies in the Clogau or Menevian black slates, and passes through many sills of intrusive greenstone. In the places where the lode is now exposed, the quartz is white and poorly mineralized; the dominant metallic mineral is galena, for which, and the silver contained therein, the lode was mined. Other minerals seen in the lode-matter are blende, chalcopyrite, arsenopyrite, and pyrites. Gold has also been obtained from this lode, 7 ounces having been got in 1889.

Cwm-heisian Lode.—On the opposite bank of the Mawddach from the Tyddyn-Gwladys Mine, is the Cwm-heisian or Cwm-eisen lode, which strikes 10° south of east, and dips towards the north, from 70° up to practically a vertical position. The lode outcrop is much obscured

by glacial drift; to the west it lies in the Vigra Beds, and towards the east in the Pen Rhos Beds. Very little greenstone is to be seen along the course of the vein. The levels by which the lode was opened have now fallen in; where the lode outcrops, the quartz is white and opaque, with very little mineral. Specimens from this lode are to be seen in the Museum of Practical Geology, Jermyn Street, and of these Maclaren has said (38, p. 453): "The invariable associate of the gold is zinc-blende, the latter being sometimes contemporaneous and sometimes prior in point of deposition; galena and pyrites also occur, and indeed the veins were originally worked as a silver-lead mine." The total reported output of this mine from 1860 to 1905 has been 12½ ounces of gold from 50 tons of quartz. It is stated also that in the early days this mine gave two large returns, aggregating 318 ounces of gold from 457½ tons of stone, but there are no figures to support this statement.

Gwyn-fynydd Lode.—On the southern flanks of the Moel Gwyn-fynydd, about half a mile north of the junction of the Afon Gain and the Mawddach, several disused levels and shafts mark the outcrop of the Gwyn-fynydd lode. Like the majority of the lodes of this district, it is found along with parallel companion lodes, as many as twenty of these having been passed through in the cross-cut which opens up the mine; one of these companion lodes is in places 20 feet thick, and is known as the Chidlaw lode. The strike of the Gwyn-fynydd vein is about 70° east of north, and the dip is towards the north, never flatter than 70°. The outcrop can be traced for a distance of about 1½ miles; at its western end it cuts across the top of the Barmouth Grits, then through the whole of the Gamlan into the Clogau Beds. Here the outcrop is thrown to the south by the Afon Gain fault, which courses down from the north. The lode then continues through the Clogau Beds into the Vigra Beds, in which it terminates against the Gwyn-fynydd fault, on the eastern side of which it has not been picked up. The lode in its course cuts through sills of greenstone, but these are not numerous. The thickness of the lode is variable: in the parts where it has been worked (i.e. in the Clogau Beds) it is from 3 to 25 feet in width, to the west and to the east it may often be as thin as 2 or 3 feet. Often the lode includes large bodies of slate and shale. The lode material consists of very white quartz, with great patches of galena, pyrites, and chalcopyrite in finely granular aggregates. In addition to the above, orpiment, pyromorphite, and mimetite (40, p. 693), arsenopyrite and blende (38, p. 452) are said to occur. Gold has only been found at those places where the vein crosses the Clogau black beds. Where it occurs it is often in a very finely divided state; sometimes, however, it is massive and arranged as in irregular veinlets. During the period 1864–1907 this mine has produced 36,116 ounces of gold from 96,569 tons of stone; during certain periods (especially 1888–92) it has furnished practically all the gold output of Merionethshire.

Summary of the Auriferous Veins.

It is to be remarked that in the Dolgelley Gold-belt not a single auriferous vein is found in any formation lower than the Clogau

or Menevian black slates. Some of the auriferous veins may extend into the Gamlan Beds, but they appear to lose their auriferous character. Again, no vein is known to be auriferous above the lower part of the Ffestiniog Flags. The only formations in this Dolgelley Gold-belt which are intersected by auriferous quartz-veins are the Menevian (Clogau), the Maentwrog (Vigra and Pen Rhos), and a small part of the Ffestiniog—a total thickness of about 3600 feet.

Throughout the gold-belt of Dolgelley the igneous intrusions (greenstones) are for the most part not of large extent; it is only the larger ones that are noted on the geological maps which accompany this paper; they are, however, very numerous, and the auriferous veins are found close to them, often, if not always, forming part of the wall or walls. The Dolgelley lodes appear to have no gossan; underground their characters appear to be similar to those they possess at the outcrop.

Reviewing the facts concerning the occurrence of the auriferous veins of Merionethshire, we may say—

(1) That the usual strike of the auriferous lodes is north-east and south-west, in some cases diverging to east and west, in others to north and south; the bulk, however, strike north-east and south-west.

(2) That there is no difference in mineral contents between the veins that range north-east and south-west and those that range east and west, or north and south.

(3) That auriferous veins are not found below the Clogau or Menevian Beds.

(4) That they occur only in black carbonaceous slates or shales, rich in pyrites.

(5) That they are associated always more or less intimately with igneous intrusions.

(6) That the lode material consists usually of quartz, often with calcite and impregnated country rock. In one case (Glasdir) the whole material of the lode consists of these impregnated shales and flags.

(7) That the most usual minerals associated with the gold are blende (sphalerite), chalcopyrite, galena, and pyrites.

(8) That the gold is usually coarse, granular or aggregated, and seldom shows crystalline faces; rarely it occurs finely disseminated through the quartz.

(9) That the distribution of the gold in the lodes is very capricious, and is not known to follow any regular law, though it appears most possible that it may be regulated by the fractures or cross-courses which intersect the lodes. Whatever the cause of the rich pockets, on them depends the future success of the mines, and until the law regulating their distribution is discovered, the mining of these lodes will always entail even more uncertainty than that which is usually associated with any gold-mining. It seems that it might be advisable, in the case of those mines now at work, to investigate as far as possible the influence that these cross-courses have on the distribution of the gold in the lodes.

(10) That in the upper portions of these lodes there is no conspicuous belt of ordinary weathering, though as work on these lodes has not

proceeded to any great depth it is possible that the whole of the lodes so far mined may be in part enriched by secondary enrichment.

Genesis of the Auriferous Veins.

The general idea of the genesis of auriferous veins is that they were filled by waters carrying gold and other minerals in solution; these waters rose from below through fissures and deposited their metallic contents in those fissures owing to—

(1) Decrease of temperature, which caused the solutions to become supersaturated and to deposit part of their contained minerals.

(2) Decrease of pressure which acted similarly.

(3) Reactions between the ascending waters and other solutions which entered the fissure along its course; a common precipitant for gold, which is also a common substance underground, is ferrous sulphate, and another is carbonaceous matter.

(4) Reactions between the ascending waters and the solid material forming the walls of the lodes.

Subsequently the lode so formed was subjected to a process of secondary enrichment, which, by solution and re-deposition of the gold content, caused a relative enrichment of the upper portions of the lode.

Applying these general principles to the Dolgelley Gold-belt, there is to be remarked, on the one hand the total absence below the Clogau horizon of any black or carbonaceous bed, and on the other the total absence of any auriferous vein below that horizon. It appears that the solutions rising in fissures through the Lower Cambrian rocks were affected only by decrease of temperature and pressure, which were not, however, sufficient to cause any important deposition of gold. At the horizon of the Clogau Beds, however, solutions entered from the wall-rocks, containing ferrous sulphate and organic matter, in both of which the Clogau Beds are rich; interactions between the two solutions caused a precipitation of the gold. As the solutions passed upwards into the Maentwrog Beds, more and similar solutions would enter, and gold would be deposited there also. The greatest amount of gold, however, would probably be deposited at the Clogau horizon. This theory tallies with what we know of the occurrence of the gold in the field; far and away the bulk of the gold has been obtained from the two lodes whose outcrops are in the black Clogau Beds.

The most ready channels for solutions to enter would be through cross-fractures, and at these points we might expect to find greater deposition of the gold. So far, we only know of this having occurred in one instance at the St. David's lode and one at the Panorama lode; but the paucity of examples may be due to deficiency of observation, for no one appears to have been on the look out for cross-courses and their possible effects.

The almost constant association of the auriferous beds with intrusive greenstones means only, I think, that the heat of the magma gave the percolating waters during the period of the intrusion a greater chemical activity, and rendered them capable of dissolving out and holding in solution more substances with which they came in contact.

Secondary enrichment is in this district only of slight importance; there is an absence of oxidized minerals in the outcrops, and there is an absence of the minerals which are usually considered to be characteristic of a zone of secondary enrichment.

The association of minerals found in the lodes, and especially the pyrrhotite, suggests deep-seated lode formations, i.e. lodes formed at some considerable distance below the then existing land surface, but which, owing to denudation, are nearer to the land surface existing at the present day.

With regard to the existence of small traces of gold in the country rock of these lodes, I was unable to determine whether such existed or not. Maclaren (38, p. 508) had made some assays, and had found minute traces (·0007 grain of gold per ton) in some of the country rocks; but it is not clear whether such gold, even if it could satisfactorily be proved to exist in the country rock, had not really been introduced into the country rock from the veins.

From this account of the gold veins of the Dolgelley Gold-belt, it may be inferred as most probable that as the mines working on lodes that outcrop in the black Clogau Beds work down below that horizon they will leave behind them the rich pockets of gold. Although it is possible that a cross-course conveying gold precipitants may cause the formation of a pocket at this lower depth, still it is not very likely. Those mines which operate on lodes outcropping in the Vigra and higher beds will, if they work down to the Clogau horizon, improve their chances of striking rich pockets of gold; it is possible, however, that they would not survive to work down to that depth. Where the lodes cut across the Clogau Beds it is most probable that the rich pockets are dependent for their position on the occurrences of cross-courses.

In examining the lodes underground it is difficult to acquire information regarding the associations of the richer pockets. In most cases it is no longer possible to examine the places where the richer pockets were found. Really, such examination could only satisfactorily be carried out by one who constantly visits the working faces and notes down all particulars which may have a possible bearing on the occurrence of these greatly coveted bonanzas. In an American mine this would be done by the mine geologist, whose special duty it is to collect geological data regarding the ore-deposits; but as such an official does not exist in English mines we can only hope that a substitute may be found in one of the regular mine officials, whose duty causes him to inspect the working faces day by day, and whose love of research prompts him to record all the geological facts that come within his observation.

Professor Lapworth, of Birmingham University, has aided me greatly in the preparation of this paper: he has spent many days with me in the field; he has shown me through the sequence of beds; he has given me the benefit of his experience in the laboratory and office work connected with this paper: for all of these aids and also for his never varying encouragement, I am truly grateful. To the officials of the St. David's Gold Mining Company, and especially to Mr. Nicholls, the general manager, I am very much

indebted for opportunities of visiting the lodes underground, and also for a vast amount of information regarding the occurrence of those richer pockets of gold, which they are always in the hope of finding.

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32. —— T. A. Readwin. *Mining Journal*, vol. xl (1870), pp. 699, 918, 940, 982; vol. xlv (1875), pp. 678, 844, 929, 1042, 1096, 1157, 1208, 1236, 1292, 1319, 1347, 1404, 1431; vol. xlvi (1876), pp. 20, 48, 75, 126, 152, 180, 233, 261, 289, 318, 345, 374, 401; vol. l (1880), pp. 135, 761, 848, 877, 904, 931, 988.
33. (1881) T. A. Readwin. *Gold in Britain*, 8vo, London.
34. (1862) T. A. Readwin. Rep. Brit. Assoc., Trans. Sect., p. 87.
35. (1904) L. H. L. Huddart. Trans. Inst. Min. and Metallurgy.
36. (1844) Dean. Rep. Brit. Assoc., Trans. Sect., p. 56.
37. (1844) Roberts. *Mining Journal*, p. 383; also (1845) pp. 6, 37, 38.
38. (1902) J. M. Maclaren. Trans. Inst. Min. Engineers, vol. xxv, p. 435.
39. (1903) Booth. *Cassier's Magazine*, vol. xxiii, No. 4.
40. —— Dr. Ure. *Dictionary of Arts*, etc., 7th ed., vol. ii, p. 692.
41. (1849) *Mining Journal*, p. 94.
42. (1865) Ibid., p. 134.
43. (1860) Ibid., p. 670.
44. (1875) Ibid., p. 1236.
45. (1865) Robert Hunt. *Mineral Statistics*, p. 36.
46. —— J. A. Phillips. *Treatise on Ore Deposits*, p. 204.

VI.—On the Stratigraphical Distribution of the Inferior-Oolite Vertebrates of the Cotteswold Hills and the Bath–Doulting District.

By L. Richardson, F.R.S.E., F.G.S.

Vertebrate-remains are by no means abundant in the Inferior-Oolite rocks of the Cotteswold Hills and Bath–Doulting District. Mr. H. B. Woodward, F.R.S., has written—

"The Inferior Oolite Series has yielded a rich and varied Invertebrate fauna, but the remains of Saurians and Fishes are very rare.

"The Reptilia that have been found include *Megalosaurus* and *Stenosaurus*, and the Fishes are represented by *Hybodus*, *Strophodus*, etc."

At the end of the work from which the above quotation is taken is a list of the vertebrate-remains which had been collected up to that year, namely, 1894.[1]

In 1904 I gave a list of the vertebrate-remains which had been recorded from the Cheltenham district,[2] and, except for the record for vertebræ and bones of ? *Ichthyosaurus* from Leckhampton and Sudeley Hills (on the authority of James Buckman & H. E. Strickland, and the more precise stratigraphical location of certain of the other recorded remains), my list was the same as that given in the Geological Survey Memoir mentioned above.

The following list is by no means a lengthy one, but as it embodies the results of quite ten years' collecting on my own part, and considerably longer on Mr. Charles Upton's part, it will be at once understood that vertebrate-remains are by no means common in the Inferior-Oolite rocks.

List of Vertebrate-Remains from the Inferior-Oolite of the Cotteswold Hills and Bath-Doulting District.

(*Those distinguished by an asterisk are in the Author's collection.*)

REPTILIA.

Dinosauria.

Megalosaurus Bucklandi, von Meyer. Lower Freestone (Hemera *Murchisonæ*). Aalenian.

Crocodilia.

Steneosaurus megistorhynchus (Deslongchamps). "Fragment of maxillary rostrum, showing three dental alveoli," "Gryphite-Grit" (*Sonniniæ*). Bajocian.

(*Vide* R. Lydekker, *Cat. Fossil Reptilia in the Brit. Mus.*, pt. i, 1888, p. 116.)

*? *Steneosaurus* sp. Reptilian jaw probably of *Steneosaurus*. *Witchellia*-Grit (*Witchelliæ*). Bajocian. Cold Comfort, near Cheltenham.

Ichthyopterygia.

Ichthyosauria.

? *Ichthyosaurus* sp. Vertebræ, etc. ? Bajocian. Leckhampton and Sudeley Hills.

(*Vide* James Buckman & H. E. Strickland, 2nd ed. of Murchison's *Outline of the Geology of the Neighbourhood of Cheltenham*, p. 80.)

[1] "The Jurassic Rocks of Britain—The Lower Oolitic Rocks of England (Yorkshire excepted)": Mem. Geol. Surv., vol. iv (1894), pp. 519–22.

[2] *A Handbook of the Geology of Cheltenham* (1904), p. 230.

SAUROPTERYGIA.

Plesiosauria.

*? *Plesiosaurus* sp. Tooth. Lower *Trigonia*-Grit (*discitæ*). Bajocian. Frith Quarry, near Stroud.

Professor S. H. Reynolds and Dr. C. W. Andrews both state that this tooth is "Plesiosaurian in type".

*? *Pliosaurus* sp. Two teeth. Top of Lower *Trigonia*-Grit or bottom of *Buckmani*-Grit (*discitæ*). Bajocian.

Professor S. H. Reynolds states that these teeth "are exactly like Pliosaurian teeth in the British Museum"—an identification confirmed by Dr. C. W. Andrews.

A piece of bone 6 inches long was obtained from the Gryphite-Grit of the west side of the Slad Valley, Stroud, by Mr. C. Upton.

PISCES.

ELASMOBRANCHEI.

Selachii.

Asteracanthus. See *Strophodus.*

Strophodus. General Note.—The teeth called *Strophodus* include two species: one in which the crown is flat (*S. magnus*, Ag.), and the other in which it is considerably elevated, and the tooth itself long and narrow (*S. tenuis*, Ag.). Satisfactory figures of these species will be found in the *Catalogue of the Fossil Fishes in the British Museum*, pt. i (1889), pl. xv, figs. 2, 3, and 4–8. The teeth which have been named *S. reticulatus* are now definitely known to belong to *Asteracanthus ornatissimus*, Ag., and are very differently ornamented and keeled.

S. magnus, Agassiz. Teeth. Aalenian, Bajocian, and Bathonian.

RECORDS: *Clypeus*-Grit or Doulting Beds.—*Hartord Bridge (near Bourton-on-the-Water); *Birdlip Hill; *Slad Valley (near Stroud); *Rodborough Hill; *Soundborough Farm (near Andoversford); Quarry seven-eighths of a mile east of Paulton Church (near Radstock, Somerset); and *Doulting.

Upper *Trigonia*-Grit.—*Holwell (near Frome: "*Acanthothyris-spinosa*-Bed"); and *Maes Knoll, Dundry (near Bristol: "Conglomerate-Bed").

Notgrove Freestone.—*Belas Knap, near Winchcombe.

Buckmani-Grit.—*Tuffley's Quarry, near the Air-Balloon Inn, between Cheltenham and Birdlip.

Base of Pea-Grit or top of Lower Limestone.—*Huddingknoll Hill, near Painswick.

S. tenuis, Agassiz. Teeth. Bajocian and Bathonian.

RECORDS: *Clypeus*-Grit or Doulting Beds.—*Doulting; *Foss-Way Quarry, near Radstock.

Upper *Trigonia*-Grit.—*Wellow, near Radstock ("Conglomerate-Bed").

Gryphite-Grit.—*Kimsbury Castle (*teste* C. Upton).

HOLOCEPHALI.

Myriacanthus sp. Fragments of palatine teeth. Identified by Dr. A. Smith Woodward. Inferior-Oolite. Cleeve Hill, near Cheltenham.

Remains of this genus of Chimæroid fish *have not been recorded before from the Middle Jurassic*: only from the Lias and Kimmeridgian (*vide* Dr. A. Smith Woodward, Quart. Journ. Geol. Soc., vol. lxii, 1906, pp. 1–4, and pl. i; *Brit. Mus. Cat. Fossil Fishes*, pt. ii, 1891, p. 43). Unfortunately the fragments from Cleeve Hill were not found *in situ*.

? *Fish-teeth.*—Mr. Charles Upton found amongst the micro-organisms of the Upper Coral-Bed (*Trueller*-hemera) a number of minute teeth not unlike those from the Rhætic which are generally called "*Sueichthys acuminatus*", only much smaller. Also he obtained a minute round *Lepidotus*-like tooth.

? *Fish-remains in the Scissum-Beds.*—Brodie, writing of the beds at Leckhampton Hill (Quart. Journ. Geol. Soc., vol. vii, 1851, pp. 208–12), which are now called the *Scissum*-Beds, observes: "Bones, scales, Coprolites and teeth of Fish are dispersed throughout the mass, and may be most readily distinguished on the surface." At Crickley Hill the *Scissum*-Beds reveal on their weathered surfaces, mixed up with the sand-grains and shell-debris, innumerable black particles, which prove to be minute phosphatic bodies. These may be the objects to which Brodie refers, but it is impossible to identify them.

The Inferior-Oolite Vertebrates of no value for the purposes of minute zoning.

From the above list it will be observed that the fish-teeth called *Strophodus* are commonest in the Top-Beds (and especially in the *Clypeus*-Grit); the Reptilian remains in the "Intervening-Beds"; while the Freestone Series (except at Huddingknoll, near Painswick, where *Strophodus* teeth are very common) contains very few vertebrate-remains indeed. The Upper Coral-Bed has yielded a few, but unfortunately indeterminate, teeth, although probably piscine.

Except, then, that the flat *Strophodus* teeth predominate in the Top-Beds, the little acuminate ? fish-teeth in the Upper Coral-Bed, and the reptilian remains in the Intervening-Beds, the Inferior-Oolite vertebrates afford little assistance in subdividing the series and are useless for minute zoning purposes.

VII.—Note on a further extension of the 'Transition-bed' and Crinoidal Limestone Band in the Middle Lias of Leicestershire.

By A. R. Horwood, Leicester Museum.

ALLUSION has been made in a previous paper[1] to the crinoidal limestone band and Transition-bed at Billesdon Coplow, and to the existence of the former at Tilton Hill near Lowesby Station. At the latter place, though the Transition-bed is not exposed in situ, the position of the crinoidal limestone bed (after making full allowance for Drift deposits), is low enough, with beds normally horizontal or with a slight easterly dip, to adduce without any doubt the extension of the Transition-bed above it at this point. Thus the crinoidal limestone band had been traced at three points—Tilton (*vide* Wilson, ibid.),[2] Billesdon Coplow, Tilton Hill—in the southern portion of the exposed area of the Rock-bed in Leicestershire, up to the time when the second paper, contributed by the author dealing with this bed in Leicestershire, was written. That is to say, it had only been found in the southern series of bold escarpments or spurs into which the district is divided. For the Twyford brook, running more or less west and east, divides the two series to which reference is directly made into a northern and a southern series, or if we include the Belvoir, Stathern, Eastwell, Holwell, and Waltham tract still more to the north, into three, with a central tract north of the Twyford brook.

[1] Geol. Mag., 1910, p. 177; 1907, p. 462.
[2] Op. cit., 1886, p. 296 et seqq.

Thus the southern portion which is free from Drift forms a series of winding sinuous escarpments right away from the Coplow to the south at Neville Holt, Hallaton, Medbourne, broken here and there by valleys now partially filled with Drift, or eroded by streams. And it has, furthermore, been lifted up by the Tilton–Loddington fault, so that some portion is now considerably out of its original position to the west.

North of the Twyford brook the Marlstone in this central tract commences to form a bold feature to the west at Burrough-on-the-Hill, and in a less degree at Thorpe Satchville—but it forms a more continuous range of hills to the north-east of Burrough, where it constitutes the backbone of the ridge and connecting spurs, all classic hunting-ground, which stretch from Somerby, Pickwell, Knossington to Ranksborough and Whissendine—whilst near Owston it bends round to join the Tilton mass to the south. But except at Burrough Hill and a few other points the Rock-bed is greatly obscured by Drift, so that sections are few and far between. This, then, may be termed the central tract.

In turn the most northerly Leicestershire *massif* is separated from the central tract by a line somewhat to the north of, but more or less parallel with, the Saxby and Bourne line from west to east, and extending from Holwell, Eastwell, Waltham, right up to Belvoir. It is connected by the Harby Hills, striking northwards from Long Clawson to Stathern, in the far north of the county.

It is at Burrough-on-the-Hill, a place noted for its fine Roman encampment, which was earlier too probably a Celtic stronghold (and where now the Spring Parliamentary Steeplechases are yearly held), that the new discovery of the crinoidal limestone band has been made by the writer since the first paper (Geol. Mag., April, 1910, p. 177) was in hand. The discovery is the more important as it relates to the central portion of the Marlstone outcrop, separated from the southern by a considerable distance.

Though I had searched carefully for indications of this very characteristic bed (band 4 at Wildbore's Lodge, Robin-a-Tiptoes, near Tilton[1]) at Burrough-on-the-Hill, I had until recently failed to find any indication of it. Except for an old trial-hole and obscure exposures, or slips covered with talus, no good section really existed on this extensive and well-known hill.[2] But in looking over some débris fallen from the higher ground on the northern extremity of the ridge, I discovered a curiously attenuated and modified form of the bed. This consisted of a thin sandy ferruginous rock with rounded and occasionally angular pebbles or inclusions of green and brown rock (chiefly Marlstone) and a few joints of crinoids. Evidently this was a conglomerate or brecciated conglomerate which represented the crinoidal limestone band at its western margin, at a period when that very constant, continuous stratum was being gradually elevated from the pelagic depths in which the normal highly calcareous band was being laid down. The marginal portion of this band lying in

[1] *Vide* J. W. Judd, "Geology of Rutland, etc.": Mem. Geol. Surv., 1875, p. 68. This bed may possibly be band 2 at Billesdon Brickyard (ibid., p. 69).

[2] Since previous visits a small quarry has been opened, but in lower beds.

a synclinal trough would naturally first be exposed to waves and littoral conditions generally, and whilst retaining something of its original character (as shown by the scattered crinoid fragments) would also include pieces of sediment derived from littoral sources, and receive later littoral detritus; and if above water or near sea-level, rolled fragments would be mixed up with the pelagic matter.

The fossils, indeed, found in the sandy ferruginous mass were those of beds lower down, e.g. *Pecten lunularis*, *Lima pectinoides*, Belemnites, etc. Whilst admitting that this rock, not being found in situ, might possibly represent our bed C at Billesdon Coplow, we consider at present it represents a higher series; but however that may be, subsequent discovery, stimulated by this find, is amply sufficient to support the correlation advanced later in this paper.

The discovery of this abnormal rock was, in fact, a clue in itself, and though not found in situ indicated the close proximity of a similar or more normal band. Nor was I disappointed in the quest, for slightly higher up, after finding a loose slab of crinoidal limestone, of a browner colour than usual, in a small covert, a shallow overgrown excavation flanking a hedge-row revealed actual traces of the real crinoidal limestone band in situ. Here again, however, the deposit was also abnormal, for instead of constituting a single thick well-marked stratum it was split up into two beds divided by 10 inches of sandy ferruginous rock, with a conjoint thickness of 3 to 4 inches.

We have thus evidence of the further extension of the crinoidal limestone band from the southern area to the northern or the central portion, indicated by an exceptional but highly interesting and instructive rock. It may be that this band has assumed the character of the thinner band (bed C) in the Billesdon Coplow section,[1] where it is broken up and irregular, in which case it would indicate a zone just below the bed B, or crinoidal limestone band horizon, if identical; but, apart from their different lithological composition, differing as they do in purity of contents, the Burrough crinoidal band is regular in extent, though attenuated. It dips at an angle of somewhat more than 10° to the south-east (just at this point), and may thus represent just the western margin of the Middle Liassic sea. The conglomeratic band, whether equivalent to bed B or C at the Coplow, is an example of shore conditions, and laid down to the west, being now displaced by earlier quarrying and weathering.

In thus establishing the original continuity of the crinoidal limestone band between the central and southern Marlstone tracts in Leicestershire we may, furthermore, venture to predict the existence of the 'Transition-bed' at the same locality, for the crinoidal band is sufficiently below the top of the hill to allow this, as at Tilton Hill, being quite 5 feet below the surface on the higher ground. So that though palæontological evidence, which alone is conclusive, is not here forthcoming, owing to the character of the section, yet stratigraphic evidence is undoubtedly in favour of its existence.

The section, in so far as it is possible to indicate its thickness, is as follows:—

[1] Trans. Northants Nat. Hist. Soc., 1907, p. 108.

		ft.	in.
A.	Broken ferruginous marly rock, sandy and much weathered. Probably representing 'Transition-bed' (bed *A* at Billesdon Coplow)	2	6
B.	Thickly bedded sandy ferruginous rock with a seam of crinoidal limestone parted by 10 inches of sandy rock (bed B at Billesdon Coplow)	2	0
C.	Blue, green, or brown marly ferruginous, laminated beds, with Belemnites, *Pecten*, *Terebratula*, *Rhynchonella*, base not seen	1	6
(?)	Bed C, Billesdon Coplow.	6	0

In so far, then, as Leicestershire is concerned the existence of the Transition-bed may be postulated in both the southern and the central tracts, whilst up to the present, though I have made search for it, it has not been met with in the northern tract. But less hopeful of finding it at Burrough as I was when it turned up at Tilton Hill, after its discovery at Billesdon Coplow, its present further extension may be said to give additional reason for prophesying its discovery in the future in the more extensive but less easily accessible district between Belvoir and Melton, where there is a thick covering of Drift.

Note.—Since my previous paper on the occurrence of aragonite in the Middle Lias of Leicestershire was published I find that aragonite has been discovered in the Cheltenham district at Churchdown,[1] Glouc. This in no way minimizes, I think, the interest attaching to my own observations, which devolved rather upon the mode of formation and composition of different parts of the Marlstone, and their physical history, rather than upon the bare record of the occurrence of this mineral itself, which is not uncommon as a shell-substance in all districts. And whilst the Leicestershire specimens are not the first recorded examples they add to the significance of the occurrence elsewhere by suggesting a definite horizon at which the general temperature of the waters of the sea in the Marlstone epoch were much warmer over a wide area, than either above or below, and not merely locally at one spot. The extension of range, moreover, of aragonite in the Middle Lias, as a mineral pure and simple, is in itself assuredly of some interest.

I have to make a correction in the same paper, having inadvertently written Barnstone for Wartnaby in reference to the occurrence of striæ on the surface of the rock-bed. In the recently published Survey memoir on the Melton Mowbray district, a photograph and diagram of the quarry where these striæ were noticed are given (plate iii and fig. 6).

In the same memoir (p. 40) it is stated that no specimens of *Amaltheus margaritatus* have actually been found in the district surveyed (Sheet 142). It may be worth while mentioning here that this zone-fossil was found by me in 1908 in that area, not in situ but doubtless derived from a local source, on the mineral line which runs down from White Lodge to the Great Northern Railway south of Harby and Stathern Station. It occurred below the rock-bed outcrop and within the area of the *margaritatus* shales, so was doubtless derived from them at this place.

[1] F. Smithe, Proc. Cotteswold Club, vol. vi, p. 349; Mitchell, *Geology of Stroud*, p. 17.

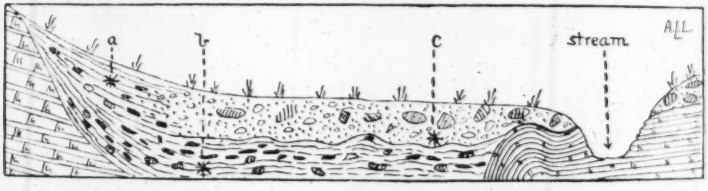
VIII.—On a Glacial Drift at Marros, near Amroth.

By A. L. Leach.

ONE mile and a half east of Amroth a small valley which opens on the coast of Carmarthen Bay at Marros shows drift deposits of much interest. The valley itself is noteworthy. Like several others in the vicinity it is deeply cut in comparison with its width; the gradient of the valley sides is as high as 1 in 2, and the depth below the bordering hills is not less than 300 feet. The stream, which now drains the valley, rises on Marros Mountain, barely 2 miles from the shore, and flows down the main dip-slope of the Coal-measures, which here are greatly disturbed by folds and faults.

The pre-Glacial origin of the valley is suggested by its depth, and fully confirmed by the nature of the drifts, which cover the floor and are well displayed on the shore, where the sea has cut into these deposits and formed a vertical section, 200 feet long, extending from side to side of the valley. Other sections are shown in the banks of the stream, which by excavating a new channel through the drifts has cut down to the pre-Glacial rock-floor. But although the stream has reached the rock it does not flow along the lowest part of the pre-Glacial valley; it has cut a new channel in the rock several feet above the base of the drifts and, as will be shown later, its post-Glacial erosion may be estimated. The chief interest of this small valley arises from the exceptional clearness of the relation between the drifts and the valley-floor. The larger valleys to the west of Marros are choked with recent alluvial deposits, and their mouths are blocked by sand-dunes and storm-beaches, which, except in one case, completely hide any glacial deposits that may be present.

The Marros Valley is excavated in shales and grits of the Coal-measures. A small anticlinal fold rises under the glacial gravel in the mouth of the valley, and probably a fault is concealed by the thick drift deposit.



Section of the Drifts at Marros, near Amroth: *a*, newer stony loam; *b*, older stony loam; *c*, glacial gravel. Length of section 200 feet. The thickness of the drifts is exaggerated.

The drift section shows at the bottom a stony loam composed of decayed local rocks, in which are embedded angular blocks and slabs derived from the slope of grits and shales against which it rests. Close to the west side of the valley this deposit is nearly 20 feet thick, but after it passes under the glacial gravel its base, being hidden by a storm-beach, cannot be seen, and the thickness shown in the cliff does not exceed 3 or 4 feet. The glacial gravel rests upon an uneven surface of this stony loam, except on the eastern side, where it rests

on the solid rock. It is a very coarse gravel, containing brown and red sandstones and red marls (Old Red Sandstone), brown grits and shales, yellow grits and quartzites (Coal-measures and Millstone Grit), with large well-worn boulders of quartz and pale quartzite. The stones are closely packed in a small gravel composed of similar materials. The thickness of the gravel is from 4 to 6 feet, its base resting on an uneven surface of the stony loam described above. The source of some of the rocks is indicated above. All the Old Red Sandstone debris is derived from rocks not only outside the basin of the Marros stream but separated from it by a deep valley in the Carboniferous Limestone: the quartz boulders are also erratics, and an igneous boulder which was found in situ in the gravel appears to be derived from some of the intrusive igneous rocks of Pembrokeshire, at least 12 or 15 miles to the north. A considerable proportion of this gravel has therefore been derived from beyond the present basin of the stream, and some of it has apparently come from the north-western side of the broad valley of the Taf. The glacial origin of the gravel is thus proved, since no agent except moving ice seems adequate to transport material into the Marros Valley over one, if not over two watersheds. At its western edge the glacial gravel is overlain by stony loam similar to that which underlies the gravel.

In their formation these drifts belong to two classes; the bottom stony loam appears to be a talus of purely local origin accumulated against the slopes of the valley during severe climatic conditions and subsequently spread out over the floor of the valley. The glacial gravel is probably not a true moraine, but water-deposited glacial debris formed as an 'outwash gravel', the material being derived from moraines higher up the valley or on the hills to the north. There is no lack of evidence of the glaciation of the district. Glacial drifts and numerous erratic boulders occur on these hills and extend many miles to the south-west in Pembrokeshire.[1] On "the ridge south-east of Marros" Dr. Strahan[2] noted a well-glaciated block of Millstone Grit.

The formation of the Marros Valley gravel as an 'outwash' deposited by glacial torrents will explain the non-occurrence of striated and scratched stones which were vainly sought for in the deposit. Any such striations would have been obliterated during the formation of the gravel by torrential streams.

A passing reference was made to the present channel of the stream which has cut down through the drifts to the rock, but, in the mouth of the valley at least, has not reached the lowest part of the pre-glacial floor. Deflected to the east side by the drift, it has cut a shallow channel along the rock slope on that side, several feet probably above the old stream-course, and now falls to the beach in a small cascade. The depth of this new channel, about 3 feet, may be taken as an indication of the erosion accomplished by the stream mainly in the post-Glacial period.

[1] R. H. Chandler, "On some Unrecorded Erratic Boulders in South Pembrokeshire": Geol. Mag., Dec. V, Vol. VI, No. 539, May, 1909.

[2] *Sum. Prog. Geol. Survey*, 1903.

NOTICES OF MEMOIRS.

The Southernmost Glaciation in the United States. By D. W. Johnson.[1]

In a recent number of *Science*[2] H. W. Fairbanks and E. P. Carey report evidences of "Glaciation in the San Bernardino Range, California", in latitude about 34° 7′ N. Concerning this interesting discovery the writer says: "It has hitherto been assumed that the southernmost point of glaciation in the United States was in the Sierra Nevadas, nearly 200 miles to the north" (north of latitude 36° N.). If their observations are correct they have found the most southern instance of satisfactory evidence of glaciation in this country, so far as I recall; but there are several records of glaciation farther south than the point in the Sierra Nevada referred to by them. Brief references to these may be of interest.

Science for November 22, 1901,[3] contained a "Note on the Extinct Glaciers of New Mexico and Arizona", by George H. Stone, in which he reported evidences of glaciation in one of the Rocky Mountain Ranges "as far south in New Mexico as a point not far north of Santa Fé" (latitude about 35° 41′). In a later paragraph we read—

"The farthest south and west I have found traces of extinct glaciers is at Prescott, Arizona. Around Prescott are numerous moraines. The highest part of the névé of this glacier could not have been much above 9000 feet. The central part of the glacier is approximately in N. lat. 34° 30′. The occurrence of an ancient glacier so far south as this was probably due to a very great snowfall owing to the proximity of the ocean . . . Probably there were then small glaciers in some of the cirques of northern exposure among the mountains directly south-east of Prescott."

R. D. Salisbury published an article on "Glacial Work in the Western Mountains in 1901", in vol. ix of the *Journal of Geology*, 1901. Beginning with p. 728 is a brief description of glacial features in the mountains near Santa Fé, between 35° 45′ and 36° North latitude. Some fifty cirques were found, and about eighty ponds and lakelets. One of the glaciers had a length of 7 miles. Moraines, striæ, and roches moutonnées were observed. In 1902 I had an opportunity to visit this same region, and I entertain no doubt as to the ample proof of local glaciation in those mountains.

In the *Journal of Geology* for 1905[4] is a paper by Wallace W. Atwood on the "Glaciation of San Francisco Mountain, Arizona". This writer describes and figures terminal and lateral moraines, and an outwash plain, and reports the occurrence of striated boulders and polished and grooved bedrock. I have briefly mentioned evidences of glaciation on this same peak, attributing a somewhat greater amount of erosive work to the glacier than is recognized by Atwood, and mentioning what I then believed to be a terminal moraine located near the mouth of a cirque.[5] The latitude of San Francisco Mountain is about 35° 21′ N.

[1] Reprinted from *Science*, N.S., vol. xxxi, No. 789, pp. 218–20, February 11, 1910.
[2] January 7, 1910. [3] Vol. xiv, p. 798. [4] Vol. xiii, p. 276.
[5] *Technology Quarterly*, 1906, vol. xix, p. 110.

F. J. H. Merrill reports in *Science* for July, 1906,[1] "Evidences of Glaciation in Southern Arizona and Northern Sonora." In the vicinity of Nogales, and elsewhere, were found deposits which he believed to be of glacial origin, while the surface had "the rolling topography and pitted surface of a moraine". Nogales is in latitude 31° 20′ N.

The above references may be but a partial list of the published reports of glaciation south of the point in the Sierra Nevada referred to by Fairbanks and Carey; I have made no effort to prepare a complete list. Of these reports, the one on glaciation near Nogales is the most striking, because of the low latitude and low altitude in which the deposits are found. The evidence as reported does not appear sufficiently convincing, in view of the strong probabilities against the occurrence of glacial deposits in the region in question. Merrill's descriptions suggest a landslide origin for the deposits which he took to be glacial. With reference to the glaciation of San Francisco Mountain I wish to add the following paragraphs.

On my visit to San Francisco Mountain I ascended the volcano by the north-west slope, and I descended into the north-western part of the 'crater'. I was impressed with the cirque-like form of the depression, and came to the conclusion that the original crater had been destroyed by stream and glacial erosion, and that the encircling cliffs were to be regarded as cirque-walls rather than as crater-walls. The great central depression of the volcano consisted of several more or less distinct cirques uniting down-stream. Near the mouth of one of these was what I interpreted as a crescentic terminal moraine, rising 150 feet or more above the valley floor. But there were certain associated features which puzzled me at the time. Up-stream from the supposed moraine the floor of the cirque appeared to be deeply buried by an accumulation of rock débris which was generally as high as, and near the head of the cirque distinctly higher than, the morainal ridge. This débris was in places, especially near the marginal walls arranged in parallel ridges trending with the axis of the valley; and in the depressions between the ridges were patches of snow and some small ponds. Thus the moraine had a steep frontal slope, but at the back merged with the ridged rock débris, which rose to still higher levels. There were some depressions in the rock débris, 25 to 40 feet deep, which I took to be ice-block holes. No bedrock was seen in the cirque floor.

During the recent meeting of the Geological Society of America, Professor H. B. Patton, of Boulder, Colorado, exhibited some photographs of the rock streams of Veta Mountain, Colorado. One of these photographs showed the high and steep front terminus of a rock stream, and resembled very closely the front slope of the supposed moraine in the San Francisco cirque. Others of his pictures showed the longitudinal parallel ridges which characterize some rock streams, with bands of snow lying in the hollows between the ridges, just as was the case in the San Francisco cirque at the time of my visit. If the concentric wave-like ridges pictured by Howe[2] were present in the San Francisco deposits, I did not notice them.

[1] Vol. xxiv, p. 116.

[2] "Landslides of the San Juan Mountains": U. S. G. S. Professional Paper, No. 67.

I am inclined to believe that the features which puzzled me at the time of my visit may have been due to landslides or rock streams. This does not mean that the depression in which the features occur is not a glacial cirque, nor that the moraines reported by Atwood are not true moraines. It simply means that I am not wholly satisfied with the evidence of glaciation as reported by myself. It would seem that the possibility of a landslide of rock-stream origin for features apparently due to glaciation must be carefully considered, especially when glaciation in doubtful localities is involved.

REVIEWS.

I.—Crystalline Structure and Chemical Constitution. By A. E. H. Tutton, D.Sc., M.A. (Oxon.), F.R.S., A.R.C.Sc. (Lond.). pp. viii+204, with 54 figures in the text. London: Macmillan and Co., 1910. Price 5*s.* net.

DR. TUTTON'S reputation for crystallographical research stands so high that the announcement of a book from his pen on a subject of such primary importance as crystalline structure and chemical constitution cannot fail to awaken general interest among those interested in crystallography, but we fear that on realizing the true scope of the book many readers will feel considerable disappointment. Far from discussing the wide subject comprehended by the title of the book, Dr. Tutton confines himself entirely to a comparatively small section of it, and, moreover, to his own contributions to that section. Everyone may not have seen the prospectus relative to the series of science monographs of which this is the first volume, and may not be aware of the intention of the publishers that "each volume will be unique, inasmuch as the author will describe chiefly his own contributions to the specific subject of scientific research with which it deals": to prevent misunderstanding it is desirable that this restriction should appear on the title-page. This volume, at least, cannot pretend to be at all an adequate discussion of the subject with which it is supposed to deal.

On the other hand, the book provides an admirable summary of the fine series of investigations upon which Dr. Tutton has for the past twenty years been engaged, and the reader may obtain a clear idea of the nature and results of the research without the labour of hunting up the original papers in the various periodicals in which they appeared. The most casual reader cannot fail to be struck with the pains taken to ensure that the apparatus and the crystals used in the investigations were of the most perfect quality obtainable, and with the indefatigability that has characterized the observational work. In the introductory pages the author, doubtless carried away by his enthusiasm, has depicted in unduly dark colours the state of the knowledge of isomorphism obtaining at the time he commenced his researches. The book is well printed, and its value is enhanced by several excellent illustrations, in one of which the author is seen in the act of grinding a crystal-section.

II.—Geology of the Little River Group.

(1) The Geological Age of the Little River Group. (2) Revision of the Flora of the Little River Group, No. II. (3) Remarkable Forms of the Little River Group. By G. F. Matthew, D.Sc., LL.D.

ON account of the discovery in this group of important and varied kinds of vegetable remains, its geological age is of much importance. This article is a brief statement of the geological evidence bearing on the age of the group. These are chiefly the relations to neighbouring formations which underlie or overlie the group, the amount of metamorphism it has undergone, and the lithological resemblance of the succession of beds to that of the Silurian strata in neighbouring districts. The conclusion is arrived at that the group is of Silurian age. There is a map showing the relations of the Little River Group to the adjoining strata.

(2) In this paper is given an account of the type of Sir J. W. Dawson's *Dadoxylon Ouangondianum*, and of two new Pteridosperms, one, *Johannophyton*, including Dawson's *Alethopteris discrepans* and his *Sporangites acuminatus* (the latter considered as fruit bracts of the former): reasons are given why these should be considered parts of one and the same plant; the fruit is shown to be a small oval seed. The other Pteridosperm is a small creeping plant with the foliage of *Aniemites*, and the fruit a small berry; it is named *Ginkgophyton Leavitti* on account of the resemblance in the form and venation of the leaves to those of the Ginkgo-tree.

This paper treats also of the Psilophyta of the formation, as well as of some new species of *Sphenophyllum* and *Whittleseya*: the Psilophyta are not thought to be typical of the genus. Six plates of fossils accompany this paper.

(3) This article treats of some animal forms and of tracts of Batrachians and Articulates of this group. A *Leaia* and a new genus of Merostome, *Belinuropsis*, are fully treated of, also the wings of two large insects are described. The footprints are partly of Batrachian and partly of 'Crustacean' type; three genera of the former are described, and three species of the latter; the Batrachian footprints are much like those of Batrachians of the Coal-measures, the others are attributed to insects or Arachnids, and are in consecutive series of tracks of various sizes.

A series of plates represent these ancient and interesting footmarks left on the sands of this old Silurian series of strata.

III.—Armenia.

IN 1906 we called attention in these columns to Dr. Felix Oswald's book on the *Geology of Armenia*. This was followed the next year by his *Explanatory Notes to accompany a Geological Map of Armenia*, and we have now before us his final conclusions on the geological structure of this area, published in Petermann's *Geographischen Mitteilungen*, 1910, under the title of "Zur tektonischen Entwicklungsgeschichte des armenischen Hochlandes". The present paper is accompanied by a map showing the Tertiary fault-lines as a series distinct from those of older date; and seven panoramic views

of the Musch Plain, the Malaskert Plain, Lake Van, and the Bingöl group. As indicated by its title, Dr. Oswald's new work is a purely tectonic one, and rounds off the story of the geology of a district which he has so lucidly and fully described.

REPORTS AND PROCEEDINGS.

I.—Geological Society of London.

April 13, 1910.—Professor W. W. Watts, Sc.D., M.Sc., F.R.S., President, in the Chair.

The following communications were read:—

1. "The Volcano of Matavanu in Savaii." By Tempest Anderson, M.D., D.Sc., F.G.S.

Savaii is one of the German Samoan Islands in the Central Pacific Ocean. It is entirely volcanic, is formed of different varieties of basic lavas, and is for the most part fringed with coral reefs.

The volcano of Matavanu was formed in 1905. The eruption was at first explosive, but since the first few weeks has been mainly effusive and accompanied by the discharge of an enormous volume of very fluid basic lava, which has run by a devious course of about 10 miles to the sea, formed extensive fields of both slaggy and cindery lava (*pahoehoe* and *aa*), filled up a valley to a depth in some places of probably 400 feet, and devastated some of the most fertile land in the island. The crater contains a lake, or rather river, of incandescent lava, so fluid that it beats in waves on the walls, rises in fountains of liquid basalt, and flows with the velocity of a cataract into a gulf or tunnel at one end of the crater. It then runs underground along a channel or channels in the new lava-field until it reaches the sea, into which it flows, and causes explosions attended with the discharge of showers of sand and fragments of hot lava, and the emission of vast clouds of steam.

The many resemblances to, and few differences from, the volcano of Kilauea are discussed.

2. "Notes on the Geology of the District around Llansawel (Carmarthenshire)." By Miss Helen Drew, M.A., and Miss Ida L. Slater, B.A. (Communicated by Dr. J. E. Marr, F.R.S., F.G.S.)

In this paper the authors deal with the stratigraphy and geological structure of a small area some 9 miles to the west of Llandovery, and to the north of Llandeilo. In a brief introduction the reasons for the selection of this region are mentioned, and the work of previous observers is touched upon.

The rocks consist of a varied series of sediments, including a coarse conglomerate, grits, shales, and tough blue mudstones; cleavage is almost everywhere intense.

The beds fall naturally into three divisions, as follows:—

C. Llansawel Group	C 3.	Pengelli Shales (Gala fauna).
	C 2.	Zone of *Monograptus communis*.
	C 1.	Clyn March or *cyphus* Grits and Shales.
B. Caio Group	B 2.	Llathige Shales and Mudstones. Zone of *Monograptus modestus*.
	B 1.	Penn-y-ddinas Grits and Shon Nicholas Conglomerate.
A. Beili Tew Group.		Beili Tew Grits and Shales.

The stratigraphical relationships are seen most clearly in the highest group (C), which is therefore dealt with first. The beds here follow each other in perfectly regular succession, with a uniform strike of E. 30° N. The basal beds, with a fauna belonging to the zone of *Monograptus cyphus*, form a well-marked ridge across country, and Upper Birkhill and Gala Beds follow to the north-west.

The second group (B) occupies a wide tract to the east of the Llansawel Group. The coarse basal deposits, and the characteristic shales and mudstones, are described from many localities.

The lowest group (A) has its greatest development on the south of Llansawel.

The structure in the eastern part of the district shows many points of interest, and is very much more complicated than in the west. The repeated outcrops of the conglomerate in the hilly region around Shon Nicholas are described in detail, and these give the clue to the structure.

The paper concludes with a general summary and a brief comparison of this district with those of Rhayader and Pont Erwyd.

II.—*April* 27, 1910.—Professor W. W. Watts, Sc.D., M.Sc., F.R.S., President, in the Chair.

The following communications were read:—

1. "On the Evolution of *Zaphrentis delanouei* in Lower Carboniferous Times." By Robert George Carruthers, F.G.S.

The small simple corals that belong to the gens of *Zaphrentis delanouei* are of common occurrence in the Lower Carboniferous rocks of Scotland. Their distribution is remarkably sporadic, but it is possible to collect over wide areas of which the stratigraphy is definitely known. A large number of specimens have been got together (some twelve hundred in all) from horizons scattered throughout the sequence. The ontogeny of these specimens has been investigated by means of serial transverse sections.

The evolutionary changes observed are confined to the disposition of the septa, which has influenced the shape of the cardinal fossula in a very marked manner. The external characters, and the spacing and curvature of both septa and tabulæ, remain unchanged.

Zaphrentis delanouei is, typically, a Tournaisian species, and it has a wide fossula, expanded inwardly. When the gens first appears in the Scottish rocks (in the Cementstone Group of Liddesdale) *Z. delanouei* is the predominant form, but is associated with a mutation (in Waagen's sense) in which the fossula is parallel-sided.

In the higher limestones of Lawston Linn another mutation appears, which, for reasons detailed in the paper, is regarded as a sport, or offshoot from the direct line of evolution.

In the succeeding Lower Limestone Group the gens undergoes further modification. Adults of the two Cementstone species are extremely rare, and the predominant form has a fossula which narrows rapidly to the inner end; in subordinate association a further mutation is also developed, in which the septa are short and amplexoid.

In the still higher horizons of the Upper Limestone Group the

last-mentioned mutation becomes predominant, and persists up to the Millstone Grit, where the septa become more amplexoid.

All these mutations, in Lœanic life, have characters seen in adults of the preceding form; tachygenesis is so marked that earlier ancestral traits are rarely seen.

Mutational percentages are given for many localities in the Carboniferous Limestone Series of the Central Valley, together with an analysis of the data so obtained.

Brief diagnoses of the four new species are appended to the paper, together with full locality-lists.

2. "The Carboniferous Limestone South of the Craven Fault (Grassington–Hellifield District)." By Albert Wilmore, B.Sc., F.G.S.

As to the lithology of the beds, some are massive, coarsely stratified limestones, made up largely of crinoids, or corals, or shells (or mixtures of these); others are well-bedded, almost flaggy, black limestones made up of finely comminuted matter, with abundant Foraminifera. There is every gradation between these extreme types. Variation in lithological character is lateral as well as vertical.

The strata are much disturbed everywhere. A series of folds strike roughly north-east and south-west, and are somewhat complex. There is considerable repetition of beds, and thickness is not so great as at first appears. This bears on the interesting question of the comparison of beds north and south of the Craven Fault.

The well-known knolls ('reef-knolls') are discussed. Their beds and those in the immediate neighbourhood are much disturbed. Irregular coarse bedding, folding, and normal long-continued weathering will explain most of their structural and other peculiarities. A typical knoll is dissected (Swinden); and it is seen to consist of folded, faulted, grey, coarsely-bedded limestone, with numerous great joints and much evidence of internal 'weathering'. Comparison of these knolls is drawn with the corresponding hills in the dark well-bedded limestones.

It is not easy to work out the exact zonal sequence, because of the disturbed character of the strata and the prevalence of glacial and fluvio-glacial drifts. The strata are apparently all Viséan (and the author does not think that there is anything lower than Middle or Upper S).

In some beds, and under some circumstances, fossils are exceedingly plentiful and easily procured.

Some corals receive more especial notice, such as *Caninia gigantea*, Mich., which is distinctive of certain beds. Other species of *Caninia* are found. New or not well-known species of *Zaphrentis* are described. The author briefly discusses the relationships of the genera *Caninia*, *Campophyllum*, *Calophyllum*, *Zaphrentis*, and *Amplexus*. New (?) species of *Lophophyllum* are also described, and the generic characters of *Lophophyllum* are discussed. There is a remarkably localized distribution of some corals, and *Syringopora* is very common in certain of the beds.

Suggestions are made as to the advisability of the disuse of some of the specific names. It is suggested that not more than four species of Carboniferous *Syringopora* need be retained.

The Rev. Prebendary Wm. Henry Egerton, M.A., F.G.S.,
a veteran Geologist (1811–1910).

II.—Zoological Society of London.

May 3, 1910.—Dr. A. Smith Woodward, F.R.S., Vice-President, in the Chair.

Dr. A. Smith Woodward, F.R.S., communicated a paper by Dr. R. Broom, D.Sc., C.M.Z.S., "On *Tritylodon*, and on the Relationships of the Multituberculata." The author had re-examined the type and only known specimen of *Tritylodon*, and in one or two points came to different conclusions from Owen and Seeley. The large flat piece of bone which forms the upper part of the snout, regarded by both Owen and Seeley as the frontal, was believed to be the upper part of the nasal. The supposed parietal was held to be the frontal. No distinct prefrontal could be made out; but there was believed to be a large distinct septomaxillary. The dental formula was believed to be $i^3\ m^7$, instead of, as supposed by Owen, $i^2\ m^6$.

Gidley's recent paper on *Ptilodus* was criticized at some length, and an endeavour made to controvert his conclusion that *Ptilodus* is allied to the Diprotodont Marsupials.

It was held that while the Multituberculates are doubtless very unlike the living degenerate Monotremes, they are more primitive than the Marsupials and not at all closely allied to them, and that till the evidence of their affinities is much greater than at present they may well be left as an independent order.

OBITUARY.

THE REV. WILLIAM HENRY EGERTON, M.A., F.G.S.

Born November 13, 1811. Died March 17, 1910.

(PLATE XXII.)

In the death of the Rev. W. H. Egerton the Geological Society has lost its oldest Fellow—one who had been elected on June 13, 1832, and had been a Fellow for nearly seventy-eight years, a record doubtless unique in the history of scientific societies. Probably the longest previous record of a Fellow of the Geological Society was that of Sir Richard John Griffith, elected a Member in 1808. He died in September, 1878, in his ninety-fifth year, after being connected with the Society for seventy years.

The fourth son of the Rev. Sir Philip Grey Egerton, ninth Baronet and Rector of Tarporley and Malpas in Cheshire, the Rev. W. H. Egerton was brother of the distinguished geologist Sir Philip de Malpas Grey Egerton (1806–81). He was educated at Brasenose College, Oxford, where he graduated in 1835, and was afterwards elected a Fellow of his College.

Inspired by the teachings of Buckland, he early gave attention to geological subjects, and in 1833 a short communication by him "On the Delta of Kander" was read before the Geological Society and published in the Proceedings (vol. ii, p. 76). The River Kander, after a course parallel to the Lake of Thun, had formerly flowed into the Aar, but owing to inundations its waters were diverted about the year 1731 into the lake. The author described the delta